National Aeronautics and Space Administration

2011 Reduced Gravity Education Flight Program

Annual Report

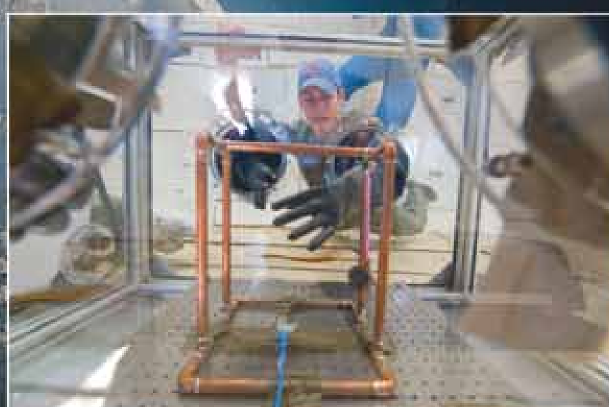


Table of Contents

Reduced Gravity Education Flight Program Overview

The Reduced Gravity Education Flight Program provides a unique academic experience for undergraduate students and educators to successfully propose, design, fabricate, fly, and evaluate a reduced gravity experiment of their choice over the course of four to six months. The overall experience includes scientific research, hands-on experimental design, test operations, and educational/public outreach activities.

Objectives

- To provide students and educators with an outstanding educational opportunity to explore microgravity.
- To attract outstanding young scholars to careers in math, science, and engineering in general.
- To introduce young scholars to careers with NASA and in the space program in particular.
- To provide a platform for students and educators to understand how microgravity affects research and testing of serious science and engineering ideas.
- To provide an opportunity for both the general public and school children to discover educational and professional opportunities available at NASA.

Significant Outcomes

- The program had a record-breaking flight season with over 500 participants.
- Around 100 college undergraduates from 13 states (representing 14 different institutions) participated in the Undergraduate Student Program. Fourteen proposals were selected for the 2011 flight year. Twelve projects focused on engineering concepts, one was physical science experiment, and one was a life science (including biology) experiment
- Over 100 college undergraduates and faculty in the System Engineering Educational Discovery (SEED) program from 9 states (representing 9 different institutions) participated in the 2011 program. The projects in this flight week were all system engineering based.
- Around 35 participants participated with the High Schools United with NASA to Create Hardware (HUNCH) flight teams that flew with the SEED Flight Week.
- Over 80 college students from 8 states (representing 14 different institutions) participated in the Minority-Serving Institution and Community College (MSI/CC) flight week. The majority of these flight teams came from first-time institutions.
- Almost 90 college students from 9 states (representing 16 different institutions) participated in the Grant Us Space Flight Week. This program is a collaboration with the National Space Grant Consortium.
- Over 95 K-12 educators from 10 states (representing 21 institutions) participated in the NASA's Teaching From Space Flight Week. Forty applications were submitted for the 2011 flight year.
- Over 40 K-12 educators from U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL) participated in the 2011 program. This is a collaboration between PPPL and the Reduced Gravity Education Flight Program.
- Each selected flight team will also be required to complete a 3-5 minute video of their Reduced Gravity Education Flight Program experience (including how the experiment was selected, hardware build-up, activities in Houston and results). Students have posted several of these videos on YouTube and other various video sites.
- An additional flight week was developed in conjunction with NASA Headquarters Office of Education focusing on minority-serving institutions and community colleges. The National Space Grant Consortium funded a flight week focusing on first-time participants. Also added were six flight teams from the U.S. Department of Energy (DOE) in conjunction with the Princeton Plasma Physics Laboratory (PPPL).
- Several flight teams have submitted papers to present at various STEM-related conferences during the Fall 2011 semester, including the AIAA Conference.

Program Overviews

Undergraduate Student Program

The Reduced Gravity Education Flight Program allows teams of undergraduate science and engineering students nationwide to propose, design, and fly a reduced gravity experiment.

The 2011 flights came from all over the United States, with participants from 13 states representing 14 different institutions. Fourteen proposals were selected for the 2011 flight year. Twelve projects focused on engineering concepts, one was physical science experiment, and one was a life science (including biology) experiment.

Overall, all 14 selected teams were able to complete their projects for flight. This included the first team from Lehigh University in Pennsylvania. This year's participants in the NASA Reduced Gravity Education Flight Program Student Program reported to Ellington Field in June. The following pages contain abstracts about each project. Full final reports are available upon request.

To date, student teams from 49 states have flown. These include 3,304 undergraduate students from 199 universities.

Systems Engineering Education Discovery (SEED)

The Education Office offered a nationwide solicitation of student applications aimed at addressing systems engineering challenges within both microgravity and lunar gravity environments. Unlike the traditional reduced gravity flight program where students propose the research to be carried out, the NASA technical workforce identified ongoing projects that are systems engineering and reduced gravity related. Selected student groups were then paired with NASA research projects under the leadership of a NASA Principle Investigator to carry out scientific research, hands-on investigational design, test operations, and educational/public outreach activities.

In addition to student involvement, one university/college faculty member was invited to fly with each team. This helped to provide faculty members with teaching materials in their classroom and is used as a motivator to increase their students' interest in systems engineering.

The 2011 flights came from all over the United States, with participants from 9 states representing 9 different institutions. Twenty-six projects were submitted from NASA Ames Research Center, Glenn Research Center, Goddard Space Flight Center, Jet Propulsion Laboratory, Johnson Space Center, and Kennedy Space Center. Nine proposals were selected for the 2011 flight year. Overall, the nine selected teams were able to complete their projects for flight. This year's participants in the SEED Program reported to Ellington Field in April. The following pages contain abstracts about each project. Full final reports are available upon request.

Minority Serving Institutions and Community College (MSI/CC)

NASA's Office of Education offers the opportunity for students attending Minority Servicing Institutions (MSI) and Community Colleges to conduct research in a unique reduced gravity environment. The 2011 flights came from all over the United States, with participants from 8 states representing 14 different institutions.

Overall, 13 of the 14 selected teams were able to complete their projects for flight. This included the first teams from Citrus College, Community College of Aurora, Fullerton College, Ivy Tech Community College, Lake Tahoe Community College, Los Medanos College, Palm Beach State College, State College of Florid at Manatee-Sarasota, Tacoma Community College College, Tuskegee University and University of Puerto Rico at Rio Piedras. This year's participants in the MSI/CC Flight Week reported to Ellington Field in June. The following pages contain abstracts about each project. Full final reports are available upon request.

Grant Us Space Flight Program

The National Space Grant College and Fellowship Program in partnership with NASA's Reduced Gravity Education Flight Program announces the opportunity for students attending colleges and universities affiliated with Space Grant consortia to conduct research in a unique reduced gravity environment. The 2011 flights came from all over the United States, with participants from 9 states representing 16 different institutions.

Overall, all 14 selected teams were able to complete their projects for flight. This included the first teams from California State University at Fresno, Grossmont College (working University of California San Diego), Northwestern University, University of Pennsylvania and Seattle Pacific University (UPenn and Seattle also worked with Rose-Hulam Institute of Technology as one team). This year's participants in the Grant Us Space Flight Week reported to Ellington Field in July. The following pages contain abstracts about each project. Full final reports are available upon request.

Teaching From Space Flight Program

Teaching From Space (TFS), located in the Astronaut Office at Johnson Space Center, manages Education Flight Projects, a NASA Office of Education Elementary and Secondary project. TFS activities are national in scope and involve formal and informal education communities and other NASA Education projects.

TFS facilitates education activities that primarily involve K-12 educators and students. These educational opportunities are designed to inspire, engage, and educate educators and students in science, technology, engineering, and mathematics (STEM) disciplines using NASA unique content and resources. TFS provides K-12 educators and students with instructional and learning experiences that utilize NASA missions, content, people, and facilities. These experiences include educator professional development opportunities and hands on student activities that connect them real time to the Agency's mission and future space exploration.

This flight week is being offered through a partnership between Teaching From Space and the Reduced Gravity Education Flight Program. This flight opportunity will allow high school teachers and students to propose, design, fabricate, fly and evaluate an experiment in a reduced gravity environment. Teachers and students will share their experiences and research in a series of interactive Web Seminars after the flight week.

The 21 teams selected for this opportunity, representing 10 states from across the United States, reported to report to Ellington Field in June and July. The following pages contain abstracts about each project. Full final reports are available upon request.

Department of Energy/Princeton Plasma Physics Laboratory

For the first time in the history of the program, the United States Department of Energy's Princeton Plasma Physics Laboratory (PPPL) is collaborating with the Reduced Gravity Education Flight Program in order to offer opportunities for K-12 educators to participate in a unique academic experience known as the Reduced Gravity Teacher Flight Opportunity The Reduced Gravity Teacher Flight Opportunity provides a unique experience for DOE teachers to propose, design, fabricate, fly and evaluate a reduced gravity investigation of their choice.

PPPL
PRINCETON
PLASMA PHYSICS
LABORATORY

The 6 teams selected for this opportunity, representing 3 states from across the United States, reported to Ellington Field in July. The following pages contain abstracts about each project. Full final reports are available upon request.

Abstracts

Top, left: Students take a team photo prior to flight.
Middle, left: Student experience her first parabola during the flight.
Bottom, left: Students taking data from their team's experiment.
Top, right: A student from The George Washington University enjoying the microgravity environment and thanking the faculty that support the team.
Middle, right: Educators taking data from their student's experiment.
Bottom, right: Educators from Warren Tech taking data from their students' experience.

Undergraduate Student Program

Participating Universities – By State
** First Time Participant (institution)*

Boise State University: Boise, Idaho
Gravitational Modulation of Calcium Signaling in Bone
Proposal ID: 2011-25295

Bone homeostasis is a dynamic phenomena in which environmental stress information is continually translated into remodeling responses by specialized sensory and effector cell populations. Under normal conditions this remodeling process promotes optimal distribution of mineralized matrix to meet biomechanical requirements. Under extreme conditions the remodeling balance can shift toward excessive resorption or ineralization, as evidenced by prolonged exposure to microgravity leading to bone loss in astronauts. In order to prevent and treat bone pathologies resulting from imbalanced remodeling it is crucial to identify the regulatory mechanisms that allow sensory cells to integrate varied and often contrasting mechanical stimuli into committed effector responses. A current model proposes that the biochemical pathways orchestrating remodeling act in simple opposition to opposing stimuli, however evidence exists that suggests a capacity for more complex regulative behavior. Parabolic flight provides an ideal environment to examine the intersection of opposing stimuli in the form of hyper and microgravity. Co-cultures of sensor (osteocyte) and effector (osteoblast) cells will be exposed to scillating gravitational conditions and the activity of calcium, an early mediator of echanosensitive responses, will be monitored. If calcium responses are shown to vary over the course of cycles between hyper and microgravity rather than to respond in simple and consistent opposition, mechanisms related to calcium flux will be implicated as potential points of regulation.

California Institute of Technology: Pasadena, California
Self-Deployable Space Structures
Proposal ID: 2011-25264

The proposed experiment aims to quantitatively investigate how various parameters affect the deployment of thin-walled carbon fiber hinges. These hinges have been used as joints for a variety of space based applications over the past decade from solar arrays to spacecraft antenna; however their deployment characteristics are not fully understood. The lack of information about the deployment characteristics of these joints has led to long delays in past missions where the numerical simulations ineffectively predicted joint behavior. The goal of the proposed experiment is to compare deployment characteristics of the carbon fiber joints in microgravity to prior numerical simulations and simulated microgravity experiments in order to improve the numerical models of prior research. Refining these models will lead to better prediction algorithms for how a joint will deploy in microgravity, and open up the possibility of widespread implementation of carbon fiber hinges on space structures.

California Polytechnic University: San Luis Obispo, California
Adaptive Control Experiment (ACE)
Proposal ID: 2011-25277

Satellites in orbit are subject to a demanding environment in which their mass properties can change unexpectedly. Currently, the attitude adjustment of most spacecraft is dependent on known values for the mass properties of the system. When the mass properties of a system change, the control dynamics of that system are altered. In addition, mechanical systems used to adjust attitude, such as reaction wheels, can degrade over time—often without detection. Both can potentially lead to system malfunctions. We plan to test an Attitude Control Simulator (ACS) that will implement an adaptive control law to adjust attitude. The ACS will consist of a platform of four reaction wheels and an Inertial Measurement Unit (IMU) coupled with analyzing software. The adaptive controller will adjust to the altered control dynamics of the system even when a reaction wheel is purposely degraded. We plan to prove that an adaptive control system is capable of adjusting attitude when the control dynamics of the system are changed or unknown. Testing the ACS in a microgravity environment is critical to simulating realistic working conditions and will allow us to compare the results to similar tests conducted on the ground. Ultimately, the performance of the ACS using an adaptive controller can be compared to current industry standards.

Students from Cal Poly monitor their experiment in parabolic flight.

Dartmouth College: Hanover, New Hampshire
Porous Media Condensing Heat Exchanger for Space Vehicles
Proposal ID: 2011-25281

NASA is designing the Crew Exploration Vehicle (CEV) to propel humanity beyond the grasp of our home planet to nearby asteroids, Lagrangian points, and eventually Mars. These long-duration missions will require light compact life support systems that can function reliably with little maintenance for periods of up to two years. One essential component of life support is maintaining a constant level of humidity in the crew capsule. Environments that are too humid or too dry are uncomfortable and can damage equipment. Current dehumidifying systems used in orbit are large, mechanically complex, and must be serviced often. To solve this problem, NASA Glenn Research Center is developing a promising new system, known as porous media condensing heat exchanger (PMCHX), to remove moisture from the cabin via the use of porous graphite. Our team will design, fabricate, and test a condensing heat exchanger that uses porous media to both extract and replenish moisture into the environment. Our product must be very light, reliable, able to handle peak moisture levels, and able to function in both microgravity and on planetary surfaces. We will select material for the cooling system pipes, a geometry for the flight-ready exchanger, and the size of the system. After designing and building our system based on the three variables we will test our prototype using flow and heat transfer modeling, finite element analysis, and analytical models. Numerical and ground test results detailing the effectiveness of our system will be compared with the microgravity flight results. The flight results will prove the effectiveness of a PMCHX in microgravity and quantify the importance of gravity on the system's efficiency.

The George Washington University: Washington, District of Columbia
Gravity's Effect on the Plateau-Rayleigh Instability
Proposal ID: 2011-25246

In this experiment we will be investigating the effects of gravity in the Plateau-Rayleigh Instability by observing the break-up of a stream of fluid in a microgravity environment and comparing those results to an identical experiment performed in a ground full-gravity environment. The Plateau-Rayleigh Instability is the reason fluids break up into smaller droplets as their streams accelerate to the ground and essentially is derived from the fluids' need to minimize their surface area due to their surface tension. The Plateau-Rayleigh Instability is the main principle behind certain technologies such as ink-jet printing and pharmaceutical manufacturing. In determining experimentally what the effects of gravity are in a stream of fluid we will be investigating the transition points between different types of flow streams that are based upon the fluid's Reynolds and Weber numbers.

Our hypothesis is that in a microgravity environment we will find the droplet frequency to decrease, the droplet size and volume to increase, and the critical time until break up to increase when compared to a similar experiment in a full ground-gravity environment. Our testing apparatus in microgravity will be a syringe pump that will create a steady stream of fluid (mirroring that of a column of fluid that would normally fall to the ground) that will be kept at a constant velocity. A flash camera system will also be set up to capture images of the stream of fluid as it is let out of the syringe pump and will aid us in determining the break-up distance as well as the shape and orientation of the droplets that will form.

Students from George Washington University explain their experiment in the TRR.

Lehigh University: Bethlehem, Pennsylvania
Zero G 'Fly-te' Trajectories
Proposal ID: 2011-25262

The purpose of this experiment is to analyze how a house fly (Musca domestica) modifies its flight trajectory when exposed to zero gravity conditions. It expands on research done by NASA on flight STS-3, March 22-30, 1982, where 12 fly puparia, 24 adult moths, 24 moth pupae, and 14 adult bees were studied. The report on this study concluded that "The results from this insect flight motion study may have raised more questions then they have answered. This has opened up new and exciting areas for future research". The presently proposed experiments can be seen as an extension to that study. In particular, flight trajectories of flies in a transparent flight tube under zero g will be mapped using multiple video cameras. The flies will be released from one end and compelled to fly towards the other end using various stimuli (sugar, etc). One major question is how an insect can fly when weight (gravity) disappears, since under conventional flight lift equals weight and thus equilibrium would not be retained, or the trajectory would be considerably altered, under zero g. Post-flight numerical analyses will be performed using point-mass equations of flight motion. The analyses will be matched to the experimentally measured trajectories.

Oklahoma State University: Stillwater, Oklahoma
Microgravity Deployment of Inflatable Gravity Simulator
Proposal ID: 2011-25274

Students from OSU monitor their experiment in parabolic flight.

For long missions through space, microgravity takes its toll on the human body. In the case of traveling to Mars for example, the estimated travel time is approximately six months. To counteract the microgravity, our team is proposing a design for an artificial gravity simulator. Our design consists of two masses (one could be living quarters and the other a power generator) each connected to an arm that is then rotated about a center point. It should be noted that one of many obstacles that occur while building and employing space structures lies within the means of only being able to use a limited amount of volume. Due to the limited amount of space available on launch vehicles, our team is proposing using inflatable beams as opposed to traditional metal structures for the arms of our simulator in order to reduce mass and volume.

Purdue University: West Lafayette, Indiana
Scaling Diaphragm Tanks in Low Gravity
Proposal ID: 2011-25254

Diaphragm tanks (also called bladder tanks) have long been in use in spacecraft to control liquid propellants during both zero-gravity and accelerated portions of spaceflight. Accelerations relevant to modern spaceflight include rapid pointing for commercial imaging satellites and docking maneuvers of various existing or soon-to-be commercial resupply spacecraft to ISS. Testing of spaceflight systems before use in space is a crucial risk-reduction step in any new hardware or mission. Parabolic aircraft flights are the most accessible and affordable low-gravity test capability for items too large for drop towers. Thus, aircraft flights are ideal for diaphragm tank testing, and often tanks need to be scaled down to become practical. However, creating reduced gravity in the aircraft always includes some g-jitter, and if the model diaphragm is too flexible, the g-jitter will obscure the true behavior (shape versus full fraction, dynamic response, etc.) of the model. This of course would invalidate the results and prevent the necessary scaling up of the flight-test results.

The experiment proposed will investigate the question of how large or flexible a diaphragm model can be to deliver accurate results amongst the unavoidable g-jitter of parabolic aircraft flight. This experiment will provide useful analysis and data for companies and researchers seeking to create and test products for reduced gravity operations, such as on-orbit fuel depots, spacecraft which dock with others, commercial imaging satellites, and similar. This experiment will also help in avoiding expensive failures due to poor knowledge of scaling issues for diaphragm tank dynamics.

Unique to our experiment are the derivation of a proposed scaling law and the creation of custom diaphragms through 3-D rapid prototype "printing" of a flexible material. These two features allow us to design a focused set of tests to use the two short days of parabolas in the Reduced Gravity Student Flight Opportunities Program (RGSFOP) to deliver new and useful data. The proposed experiment will explore the practical limits of static and dynamic testing of scaled diaphragm tank systems in the important but imperfect zero-gravity of the aircraft flights and deliver data for others to use for choosing a suitable scale for future experiments and validation tests. The observation of the deformation of the carefully scaled diaphragms inside a collection of scale tanks will allow us to analyze exactly how large can a model be scaled and still perform well in the g-jitter of the aircraft. And furthermore, by varying the thickness of the actual diaphragm a proposed non-dimensional stiffness parameter will be evaluated. This scaling parameter is developed for a dynamic response scaled with the radius of the tank, g-jitter accelerations, material properties of the diaphragm material, and diaphragm thickness. This experiment is not feasible in 1-g, as reduced gravity is an integral part of its completion. Diaphragm tanks are important to study in this manner because the complexity of the deformable solid-liquid interaction makes it a difficult task to analyze using CFD programs.

State University of New York at Buffalo: Buffalo, New York
Line of Sight Relative Attitude Determination for Two Satellites
Proposal ID: 2011-25266

With an increasing number of missions involving interaction between spacecraft, there is a need for a simple method for determining the relative attitude amongst one another. The proposed method utilizes line of sight measurements between two satellites and one common reference point to determine the relative attitude. Because line of sight measurements between two bodies and a third point constitute the sides of a triangle, a triangular constraint allows for the third point to be arbitrary as long as it is common between the two bodies. The experiment consists of two satellites equipped with position sensing diodes which determine the line of sight vectors to the other satellite and reference beacon. An algorithm is run on the satellite's onboard microcontroller to determine its relative attitude to the other. Using this data, reaction wheels can be used to orient one satellite with the other, thus further validating this simple method. The relative attitude can be determined independent of range by measurements and communication between only the two satellites. The third reference beacon is arbitrary and does not require communication with the rest of the system.

University of Florida: Gainesville, Florida
Attitude Control Verification Using Miniature CMGs
Proposal ID: 2011-25261

Small satellites, in particular the nano- and pico-class, are becoming increasingly common in both industry and academia. The development of a small satellite industry has led to the adoption of the "Smaller, Faster, Cheaper" model for earth orbiting space missions (Karatas). This idea has led to shorter development cycles, reducing costs and increasing the flexibility of potential missions, therefore allowing them to be very responsive to new opportunities and technological advances. One area of functionality that has received the attention of the small satellite community is attitude control. The ability to rapidly retarget a nano- or pico-class satellite and then precisely point it to a desired position can greatly increase the capability of a potential mission. Additionally, control moment gyroscopes (CMG) have extensive heritage on larger space platforms (Pothiawala and Dahleh), but are non-existent in these smaller satellites. Due to their torque amplification capabilities, CMG's are a particularly effective actuation system which could potentially expand payload possibilities of nano- and pico-class satellites. The University of Florida has developed a miniaturized CMG system specifically for these smaller satellite classes; however, the effectiveness of this system is difficult to verify in 1g labs because of the inability to produce full three degrees of rotational freedom.

The objective of this proposed microgravity experiment is to demonstrate the capabilities of the UF pyramidal CMG configuration to provide three-axis attitude control of a pico-class satellite by performing rapid retargeting and precision pointing maneuvers. This experiment will validate that four single gimbal CMGs in a pyramidal configuration will provide attitude control to an experimental test bed while reducing the risk of encountering singularities. Data will be acquired through an inertial measurement unit and tracked via personal computer and data acquisition software. The numerical results will be compared with visual results to determine if the CMG sufficiently affected the attitude.

University of Washington: Seattle, Washington
Reduced-Gravity Fluid Transfer Experiment
Proposal ID: 2011-25248

Students at the University of Washington have identified a method to potentially solve many of the problems experienced with the transfer and measurement of liquid in microgravity. Building off the success of our colleagues' experiment in developing the Rotational Damping of Slosh in Microgravity (RDSM) mechanism [5] in the 2009-2010 NASA- Microgravity University program, we have designed a system that transfers and measures liquid in a rotating fluid tank. This experiment utilizes the physical principle that the centripetal force induced by the rotating tank in reduced gravity causes the liquid inside to stabilize and gather on the inner wall of the tank. By inserting capacitance sensors through the walls of the tank, the difference between the dielectric constants of the air and liquid inside the tank allow for the liquid volume in the tank to be determined. Furthermore, the rotating tank and its tapered geometry cause the liquid to accumulate towards one end of the tank. Because of this, a tube can be inserted into this reservoir and the liquid can be extracted via a small pump and transferred to a secondary collection tank. The flow out of the tank will be measured using a volume flow rate meter, and verified by measuring the fluid collected in the secondary collection tank once gravity is restored. This fairly simple system allows for measurement and transfer of large or small quantities of liquid.

Utah State University: Logan, Utah
FUNBOE 2.0 (Follow-Up Nucleate Boiling On-flight Experiment)
Proposal ID: 2011-25275

As mankind continues to explore space, there is an increasing need for reliable, more cost-effective thermal management systems. Due to the high heat transfer rates associated with nucleate boiling, this process could prove to be a viable option for such microgravity systems. However, further experimentation in microgravity environments is needed to understand the fundamental effects of system parameters on nucleate boiling dynamics and determine its range of applicability.

FUNBOE 2.0 is a follow-up study to the original FUNBOE project that was flown during the 2009-2010 RGSFOP program. FUNBOE provided many insights to the nucleate boiling phenomenon that were previously unreported. While FUNBOE found many interesting boiling characteristics, FUNBOE 2.0 seeks to explore several of these results in more detail, including:
i. Investigating a broader range of heat fluxes to completely map the boiling curve and investigating bubble jets especially near the critical heat flux (CHF)
ii. Further resolving the minimum heat flux required to initiate boiling for various heating element surface geometries and the associated pre-boiling and boiling characteristics
iii. Extrapolating the understandings of thin-wire boiling developed with FUNBOE by testing the effectiveness of creating seed bubbles with a 2-D array of microheaters in order to enhance cooling.

West Virginia University: Morgantown, West Virginia
Electromagnetically Enhanced Fluidized Beds in Microgravity
Proposal ID: 2011-25287

Fluidized beds are a current technology used to achieve high levels of contact between a solid particulate and a flowing gas or liquid. This technology has been implemented in various applications ranging from filtering to combustion. While it has proven benefits in an environment where the gravitational force is influential, minimal research of fluidized beds in a microgravity environment has been conducted. This is a critical issue as this technology may have the potential to be utilized in microgravity for the same range of applications as on Earth. Two distinct methodologies have attempted in previous work to simulate the gravitational force in microgravity by: A.) directing a Coulomb force and B.) use of an electromagnetic gradient field on charged particles. The latter demonstrated that it is possible to replace the gravitational force by an electromagnetic force.

This current research effort intends to enhance the performance of the previous works by incorporating a rotating time-dependent electromagnetic field. Inducing a rotating magnetic configuration is theorized to increase the amount of mixing between the solid particulate and the fluid, air. Further mixing between the two phases will increase the effective reaction surface area thereby optimizing the efficiency of the fluidized bed when utilized in microgravity applications. A rotating fluidized bed can be enhanced by many variables including, but not limited to, the mass flow rate of the flowing gas or air and the angular rate of the rotating electromagnetic field. Rather than have a physically rotating mechanical device to induce the field, the rotating field will be formed by switching a series of coils on and off at specified time intervals, corresponding to the electromagnetic angular rate. A decrease in the time interval is expected to increase the mixing between the particles and the air up to a threshold, where eventually reducing the time interval any further may negatively impact the mixing. An increase in the flowing gas rate supports an increase in surface area interaction, although is limited by a similar threshold. This work is a culminating effort to create optimized reaction mixture techniques for future space-based microgravity applications in which filtration and/or chemical reactions must be optimized.

Yale University: New Haven, Connecticut
Solidification of Fluids and the Formation of Mushy Layers
Proposal ID: 2011-25267

When fluids are solidified in microgravity, many of the underlying processes that lead to deleterious effects when the same systems are crystallized on Earth can be avoided. Understanding the fundamental physical processes governing the solidification of multi-component fluids and the formation of so-called mushy layers also has wide application to oceanography, materials science, and planetary science. NASA frequently sponsors experiments on the solidification of ice crystals or binary alloys, some of which have been performed aboard the International Space Station. The proposed experiment aims to quantify the effects of various gravitational conditions on the solidification of a transeutectic sodium acetate solution. This experiment is ideal for parabolic flight because its science goals benefit greatly from data collection in the four different accessible gravity conditions and the solidification time scales are the same as the length of a typical microgravity episode. Video of the solidification and fluid mechanical processes is collected with a high-speed, high-resolution camera. Solidified samples will be analyzed after the flight to determine crystal grain size and the abundance of channels or macrodefects. The test article is engineered to safely and efficiently achieve the experiment's science goals. An extensive outreach program is proposed to inspire younger students, including historically underrepresented populations, to pursue further education and careers in STEM fields.


A memorial plaque flown for a former Yale student.

Systems Engineering Education Discovery (SEED) Students

Participating Universities – By State
** First Time Participant (institution)*

State	Institution	Page		State	Institution	Page
CA	California State Polytechnic University, Pomona*	**12**		TX	University of Texas at El Paso	**15**
CO	Warren Tech and Lakewood High School (HUNCH)	**18**		TX	Barbara Jordan High School/Cypress Woods High School (HUNCH)	**17**
ID	Northwest Nazarene University*	**13**		TX	Clear Springs High School (HUNCH)	**17**
KY	University of Kentucky	**13**		WI	University of Wisconsin at Madison	**15**
MO	Washington University in St. Louis	**16**		WI	Carthage College	**12**
NE	University of Nebraska at Lincoln	**14**		WY	East High School (HUNCH)	**17**
OR	Portland State University	**13**				

California State Polytechnic University, Pomona: Pomona, California
AE-COX: Atmospheric Entry with Control in One Axis

The project is conceived as a flying test article and proof of concept of a novel emergency back-up system designed to address the problem of an entry capsule with arbitrary initial angular rate and attitude that, in the absence of nominal control capability, needs to fly a safe emergency atmospheric entry. The proposed control concept permits the arrest of a tumbling motion, orientation to the heat-shield-forward attitude, stabilization and the attainment of a ballistic roll rate of a symmetric spacecraft with the use of control in one axis only (with as little as 2 thrusters) This concept is documented in the paper “Spacecraft Maneuver and Stabilization for Emergency Atmospheric Entry with One Control Torque” published in the AIAA Journal of Guidance, Control, and Dynamics in 2008. Paper 0731-5090, vol.31, no.3 (pp. 629-640) This concept was disclosed as a NASA Disclosure of Invention and New Technology with the eNTRe Tracking Identifier 5022510 with the title “Maneuver and Stabilization with Control in One Axis”. To date, the only design option to cover for the absence of the nominal control system during an atmospheric entry is to add another redundant control system similar to the nominal. The Russian Soyuz only provides redundancy for the roll jets, making the assumption that the spacecraft is already placed at the right attitude with no initial rates. The Apollo capsule had 2 RCS or, in other words, two complete nominal 3-axis control systems. The same design is expected for the Orion capsule. The objective of the proposed control concept is to provide a very low mass back-up system with control in one axis only that, with as little as 2 jets, could have a safe emergency atmospheric entry in the absence of nominal control functionality. The proposed project is intended to show that a safe entry with control in just 1 axis can be accomplished. This capability would result in the reduction of hardware mass and complexity in future manned and unmanned spacecraft designs. Furthermore, for a capsule designed with 2 complete RCS systems, the innovation could be included as an extra back-up emergency system that would increase crew safety and mission success with the addition of little mass, that is, with low mass cost.

NASA Technical Contact: Eduardo Llama – Johnson Space Center

Carthage College: Kenosha, Wisconsin
Non-Invasive Fluid Volume Measurement

This project is to demonstrate microgravity Fluid Vessel Quantity measurement using non- invasive PZT sensors and actuators. In a microgravity environment the goal is to measure PZT responses to establish quantities of fluid using 3 small tanks containing known volumes of water. The PZT based system has been used on similar composite tanks and will be provided by NASA, KSC. The flat, flexible PZT actuators and sensors are attached to the walls of the three demo tanks. The data will be analyzed Post flight using Frequency Response Functions and other processing to

Students and a faculty member from Carthage College monitor their experiment in parabolic flight.

assess the results using NASA PI developed software. The students will aid in developing the mechanical and electrical setup and collecting the data using a laptop. This project, investigating the physics of microgravity fluids involves at least several disciplines in mechanical and electrical engineering,. The system requires data acquisition and experimental setup ability and will enhance university student real world problem solving skills. A current challenge for a space based propellant depot and other space missions is the determination of weightless fluid quantity, especially on cryogenic fluids. Cryogenic fluids are planned for use on long duration space flight. The goal is to minimize heat transfer and reliability determine fluid quantity or mass, thus a non-invasive measurement system, like being investigated here is ideal.

NASA Technical Contact: Rudy Werlink – Kennedy Space Center

Northwest Nazarene University: Nampa, Idaho
Hydrophobic Surfaces in Micro Gravity

The recovery of valuable water from waste management systems can be hampered by the entrapment of the liquid within the waste treatment device. Water adheres to equipment surfaces due to surface tension forces. The surface tension between water and the equipment surface varies depending on the type material or coating used. The experiment would determine the propagation rate of the water across the surface of a plate at different air velocities. Three surfaces should be compared: An anodized aluminum surface to represent typical hardware, an aluminum surface coated with PTFE (hydrophobic), and a stainless steel surface. The recovery of water for human space exploration missions directly affects mission planning and life support systems development needs and decisions. The recovery of water from solid waste can reduce the need for resupply water that must be launched from earth thereby reducing mission costs. The waste management equipment is one element of a total life support system that includes air revitalization, recovery of water from urine and hygiene water, and ISRU (In-Situ Resource Utilization). Knowledge of the different life support hardware capabilities is required to determine spacecraft and space habitat system needs such as power management, habitat volume, and crew time usage, etc. Water recovery from waste is a critical driver in the design of Waste Management Technologies. The development of equipment that closes the life support loop reduces mission costs and crew time life support related activities and increases mission capabilities by allowing longer mission times and increased crew time available for scientific and exploration goals. The proposed experiment will aid in the development of current and future Exploration Life Support Waste Management hardware.

NASA Technical Contact: Gregory Pace – Ames Research Center

Portland State University: Portland, Oregon
Heating/Lighting in Microgravity

Investigate how the heating and lighting from incandescent and halogen bulbs changes in micro and partial gravity. Observe parameters such as voltage/current, temperature. record video of filament motion; and measure heat and light production. Extra challenge: visualize the change in buoyancy-induced convection flows both inside and outside the bulb. Incandescent and halogen bulbs can serve as sources of both heat and light, for example in plant growth chambers or to heat the interior surface of a vacuum chamber to bake off contaminants. There is some limited scientific and anecdotal evidence that while such bulbs do operate in microgravity, the behavior is different due possibly to the lack of natural convective flow of the gases inside and outside the bulb. This different behavior may impact the lifetime and efficiency of the bulb. Incandescent and halogen bulbs are primary candidate sources for situations and instruments which require heat and/or light. Commercial bulbs would be very inexpensive solutions, but they must perform with sufficient lifetimes for long space missions, with steady efficiency and output.

NASA Technical Contact: Darrell Jan – Jet Propulsion Laboratory

University of Kentucky: Lexington, Kentucky
Bubble Free Syringe

A dual plunger syringe was designed for a microgravity fluid physics experiment to separate the gas bubble from a fluid in a medical syringe and then dispense the liquid contents. This design was tested for the first time during last year's SEED program reduced-gravity flights. Based on the results from our previous testing, additional testing is required to discover the appropriate materials and geometries for successful bubble removal. The experimental syringe has two plungers. The innermost plunger is consists of a porous plate that is “wetting.” The outer plunger is the typical shaft contained in medical syringes. A conventional liquid syringe contains not only the liquid, but also a gas “ullage” bubble that will cushion liquid volume changes caused by temperature changes that affect the liquid density. This experimental system will remove the gas bubble by depressing the inner plunger and allowing liquid to accumulate behind the porous plate. Afterward, the outer plunger is depressed to expel the liquid from the syringe. Previous data shows that the plastic material that was chosen as the inner plunger material may not be ideal. Materials with different wetting properties will be used in this experiment. The experiment will consist of an outer containment glovebox, with prepositioned cameras that would image the gas bubble and liquid. In addition, mixing of the fluid will be investigated. Before “injection”, a solution will be mixed using the motion of the inner plunger. Mixing will be considered successful if all of the solute dissolves into solution during the trajectory. The project combines mechanical and structural engineering for development of the flight hardware, fluid mechanics for the ability to develop the experiment, and data collection techniques to record relevant data. All of these disciplines will need to be integrated for a successful project. This project directly addresses gaps identified by the Human Research Program, which resides within ESMD.

Students from UK monitor their experiment in parabolic flight.

NASA Technical Contact: Aaron Weaver – Glenn Research Center

University of Nebraska at Lincoln: Lincoln, Nebraska
Microgravity Propellant Management Device Investigation

This project is an extended study of a fluid equilibrium and slosh experiment preformed through last year’s SEED program. The Orion CEV contains liquid biprop and monoprop propulsion systems for orbital maneuvering, trans-Earth injection, and reentry burns. Propellant management devices (PMD) provide gas free propellant in zero gravity conditions to the main engine, auxiliary engines, and reaction control systems, to ensure adequate system performance is maintained. Due to the large quantity of propellant for this particular spacecraft, understanding liquid slosh during docking, zero-G, low-G, and high-G maneuvers is important for maintaining dynamic control and determining the additional structural loads. It is also important to understand how the propellant settles during long duration exposure to microgravity conditions with respect to Orion’s specific tank design for propellant mass gauging and center-of-gravity control. In this project the students will be creating a test model of one of the Orion Crew Module propellant tanks including the diaphragm PMD. Since the actual tanks are reasonably sized, a full scale test tank should be used. Matching of propellant properties to the experimental fluid (surface tension, density, etc.) must be considered. In addition to the full scale crew module tank test, the students will also be producing a much smaller service module tank model for the purpose of validating zero-g fluid equilibrium results obtained from the computational fluid dynamics code Flow3D. The students will need to develop a test plan and apparatus for imparting and measuring different liquid slosh forces. An attempt at isolating the test apparatus from the external forces of the plane should be attempted to provide the most accurate results. This includes achieving an accurate acceleration profile of the aircraft such that vibrations and other effects from the plane can be considered when interpreting the data. The first parabolas for each test set can be used to ascertain the equilibrium position for the fluid in the tank in zero gravity and the time it takes for the fluid to settle in that position while the rest of the test runs will be focused on the slosh testing. Ultimately, the results from this experiment will be used to both validate and improve analytical models of propellant slosh. In this project there are a number of complex systems challenges to overcome. While the majority of the physics will be fluids and aerospace related, there is a need for good electronic equipment and data acquisition methods. Isolation of the system from external interference as well as understanding the mechanics of the whole experiment is important as we will try to obtain higher fidelity data than the previous experiment. Fluid visualization is also very important in this study, the raw visual data can be converted into quantitative information. Students and the project will benefit from forming an interdisciplinary team and assigning tasks appropriately. The Orion crew exploration vehicle is the next generation spacecraft for human space exploration with Lockheed Martin as the prime contractor. As part of the Constellation Program and Vision for Space Exploration, Orion directly supports NASA’s Exploration Systems Mission Directorate by providing the agency with safe and reliable access to the International Space Station and eventually the lunar surface. In both instances, astronauts will be given great opportunity for scientific study in astrophysics, planetary geology, biological sciences, and impacts of long term human exposure to zero gravity conditions, just to name a few.

NASA Technical Contact: Scott Walker – Johnson Space Center

University of Texas at El Paso: El Paso, Texas
Evaluation of Exothermic Welding in Reduced Gravity

Success of long-duration spaceflight and future space exploration missions will be highly dependent on maintenance and repair challenges. Because of mass and volume constraints to carry spare parts onboard spacecraft, an evaluation of new approaches for maintenance and repair is necessary. Exothermic welding is well known as a reliable, low-energy consuming method for connecting copper wires or cables. However, this method typically relies on Earth's gravity for moving the molten metal from the combustion zone to the parts that have to be welded. The proposed experiment will test the special approaches and design we have developed for conducting the exothermic welding process in a reduced gravity environment. The testing apparatus involves a set of industrial devices used for exothermal welding, modified for operating in a microgravity environment. The devices are placed in a sealed chamber, which, along with other safety measures, ensures safe testing onboard the reduced-gravity aircraft. After the flight, using characterization techniques available at UTEP, the quality and properties of the welds obtained in reduced gravity will be compared with those of the welds obtained in a standard 1-g environment.

One of the Exploration Systems Mission Directorate (ESMD) strategic goals this aligns with is to focus the human spaceflight program on exploration. By developing reliable construction techniques that can be used in a microgravity environment, it provides NASA with the capability to construct larger structures such as space stations or transfer vehicles while on orbit. This will be desirable when designing a Transfer Vehicle / Habitat to transport humans to Mars. Another strategic goal of the ESMD is to form appropriate partnerships with the emerging commercial space sector. By perfecting reliable on-orbit construction techniques this could allow commercial entities to provide the lifting and transport of the individual structures to orbit (thus expanding the scope of NASA's Commercial Orbital Transportation Services, COTS Program), for on-orbit assembly by astronauts.

NASA Technical Contact: Amber Gell – Johnson Space Center

University of Wisconsin at Madison: Madison, Wisconsin
Fuel Gauging in Microgravity using ECVT

For future space explorations, an existence of an orbiting "gas station" supplying liquid hydrogen and oxygen to spacecrafts on their way to Moon, Mars, and other planets will make the future space missions more efficient and sustainable. Furthermore, variety of liquids is used in spacecrafts (low or zero gravity) for human survivability and for other necessary spacecraft operations. Accurate measurement of mass/volume of these liquids in storage tanks under micro/zero gravity conditions is important for the craft and space station management. Under NASA's IPP program engineers at GSFC are in the process of completing fabrication of a proximity/near field noninvasive sensor which will allow performing reliable and robust method of mass gauging of liquids stored in a tank subjected to zero/microgravity environment. The sensor involves a small size tank embedded with capacitive electrodes along the tank's inner surface. A data acquisition system is mounted outside the tank to measure mutual capacitance between electrodes. The students selected for this project will be involved in field testing of this sensor under simulated zero/microgravity environment provided by NASA's zero gravity aircraft. The team will be required to devise accessories that will be required to mount the sensor described above into the slot provided by the zero gravity aircraft. The measured data taken during the flight along the zero gravity parabolas will be then processed to estimate mass of the fuel stored inside the tank. The ECVT technology, described above, is a multipurpose technology and can be used to monitor the flow of liquid and gaseous fuel through pipes, buffer tanks, and other components used in a propulsion system. More importantly, the ECVT technology can be used to monitor flow of fuels at critical locations of propulsion system when the propulsion system is operating under a severe space environment such as zero gravity and varying temperature, pressure conditions.

Application of the ECVT technology into current propulsion systems would help study fuel flow behavior under varying external conditions and will suggest solutions to improve reliability and efficiency of a propulsion system. NASA's future exploration missions involving long duration travels will demand 100 % reliability of proper functioning of onboard propulsion system on future spacecrafts. One of the important functionality of a 100% reliable propulsion system is to maintain smooth supply of fuel to the onboard engines and thrusters when requested by remote commands. Proper and timely supply of fuels and fluids to onboard spacecraft components becomes more critical when the propulsion system has to operate under harsh space environment such as zero/microgravity and cryogenic temperatures.

NASA Technical Contact: Manohar Deshpande – Goddard Space Flight Center

Washington University in St. Louis: St. Louis, Missouri
Measuring Localized CO2 in Microgravity

Students WUSL and NASA mentor, Jennifer Zumbado monitor their experiment in parabolic flight.

While there are requirements and measurements that govern carbon dioxide (CO2) levels within the Space Shuttle and International Space Station (ISS) environments, recent evidence points to CO2 exposure symptoms within the crew. It is hypothesized that the inhaled CO2 levels experienced by the crew on orbit may be greater than the overall average cabin levels. This has led the Medical, Life Science and Engineering communities to begin to investigate both the requirement limits and the variables that govern the CO2 levels and their circulation. This project would serve as a pathfinder for a future ISS Detailed Test Objective (DTO) to identify and characterize the inhaled CO2 levels experienced by the crew on orbit. Before such a DTO could be performed to observe long term effects, this project would validate that a measureable effect can be seen, as well as validating measurement techniques and hardware. This project will demonstrate a device for measurement of the fluctuation of the partial pressure of carbon dioxide (ppCO2) close to the wearer’s nose and mouth. In addition, the test will identify the local variation of ppCO2 relative to both the resting and exercising metabolic rates of the subjects, and measure the variation for both still subjects simulating sleep and subjects in motion about the cabin. It will identify if and how these differ in a microgravity environment relative to a 1-g environment, and compare the measurements to a baseline measurement of global ppCO2 in the aircraft cabin.

Multiple systems contribute to the level of CO2 experienced by the crew including the vehicle Environmental Control and Life Support System (ECLSS), the Extravehicular Activity (EVA) suit, the sensor avionics, in addition to the human themselves. Any exploration of the root cause of the symptoms being experienced and development of solutions will require a systems integration approach. While the requirements are developed from a bottoms-up assessment of human tolerance to such constituents, a top-down integrated perspective must be applied to yield an appropriate (both in terms of performance and cost) solution. The intent of this flight demonstration is to act as a precursor to a future ISS DTO that plans to measure inhaled ppCO2 on orbit within the cabin environment over a period of days, and within EVA suits over the duration of an EVA. Currently, there is debate about how the levels of ppCO2 should be measured and characterized within EVA suits. The effects of exhalation within the helmet and the active airflow for CO2 washout can cause great variation of ppCO2 at various locations of the helmet with changes in crew metabolic rate. This project will collect engineering data of the levels of ppCO2 near the crew nose and mouth, and identify unique effects of microgravity leading to ppCO2 stagnation and local variation. These results may provide rationale for the funded research ISS DTO and provide lessons learned for developing a DTO test plan. The end result of the ISS DTO will be to develop and validate requirements for acceptable ppCO2 management on orbit and within EVA suits, including modifications to procedures and flight rules.

NASA Technical Contact: David Alexander, Jonathan Dory and Jennifer Zumbado – Johnson Space Center

HUNCH Participants

The High Schools United with NASA to Create Hardware, or HUNCH, project provides work experiences to inspire high school career technology and engineering academy students to pursue careers in science and engineering fields. HUNCH is a collaborative effort among NASA Space Operations and Exploration Systems mission directorates and Marshall Space Flight Center's Academic Affairs, Training and Crew Operations, and Ares Project offices. They provide "work-world" experiences for students by engaging them in the design, fabrication and rapid prototyping of multiple products for use in the ARES I mock-up. High school students will be challenged to meet NASA's work requirements as they coordinate to plan, design and model hardware for the Ares I upper stage and J-2X engine. Students will use a 3-D plotter for integration of parts and materials.

Barbara Jordan High School: Houston, Texas and ***Cypress Woods High School:*** Cypress, Texas
ISS On Orbit Flying Camera

We are developing a remote control camera that is intended to be free flying inside the ISS and controlled by ISS operations on earth. We are investigating functionality of the cameras propulsion and control systems in a micro-g environment. The camera enclosure will be semi-spherical in shape and propelled by small battery powered ducted fans internal to the camera enclosure. It will be remotely operated via radio signal and will be capable of both video and still camera pictures that can be transmitted to ISS mission control. This camera will allow collection of images related to hardware configuration, orientation and condition without interruption of the ISS Crew. Our experiment will consist of a clear Plexiglas / Lexan containment enclosure and a semi-spherical radio controlled camera enclosure approximately 6-8 inches in diameter. Radio control frequency will be 2.4 Ghz. We will collect and record data manually using experiment provided video cameras and data sheets for later playback and analysis. Translation in all six degrees of freedom will be tested (roll, pitch , yaw, and translation in the x, y and z directions). The video cameras will record the flying cameras control system reaction to input signals in the reduced gravity environment. Testing the flying camera in a micro g environment allows testing the flying eye flight control system in all six degrees of freedom simultaneously which cannot be done in a one g environment. We will be quantifying the flying camera's flight control stability and functionality in a reduced gravity environment.

Clear Springs High School: League City, Texas
Aeroponics for Legume Food Growth Chamber


Students from Clear Springs HS monitor their experiment in parabolic flight.

We are developing an aeroponic food growth chamber that can function in a microgravity environment. Last year we tested the watering system onboard the Zero-G plane. This year we have made the necessary modifications to the watering system. Additionally, we will be measuring the CO2, temperature, and humidity of the food growth chamber. The knowledge used from this experiment will be applied to the development of a food growth chamber that is proposed to supply the ISS crew with fresh food. The experiment is contained inside a box constructed from Lexan, which will be placed inside a NASA glove box to provide double containment of the water that is required. The experiment relies on a COTS submersible water pump, fan, PVC piping, micro-spray nozzles, micronic mesh, high intensity LED lighting, and various sensors. The plants will be of the legume family. We will collect and record data from the readings received from the sensors. During microgravity conditions, data will also be collected by student observations and will be recorded on a digital recorder and camera.

East High School: Cheyenne, Wyoming
The Dispersion of Scents in Microgravity

We are developing a systematic procedure to release fragrant organic essential oils under microgravity conditions. By the use of a specialized sensor for volatile organic compounds, we will measure sensor readings for specified areas of dispersion of the fragrant oils. The knowledge used from this experiment will be applied to an experiment, proposed to improve the scents onboard the ISS for astronauts. Our experiment will consist of a clear Lexan container. Within the container will be small vials of essential oils. A sensor board with a volatile organic compound sensor attached will be hand moved around the glove box in order to measure the dispersion of the organic oils at different locations within the glove box. We will collect and record data from the readings received from the sensor board to a netbook. During microgravity conditions, the sensor will be placed at different locations within the glove box to provide readings on the dispersion of the organic oils.

Warren Tech and Lakewood High School: Lakewood, Colorado
Plant Growth Chamber

We are investigating how a complete plant growth system can function in zero g. All aspects of plant growth are being addressed: lighting, watering, fertilization, air circulation, rooting systems, accessibility, food value and harvesting. Additionally, some of our students would like to investigate the emotional response astronauts have while caring for plants on the ISS. Currently our experiments consist of four different but related approaches to the same goal (growing plants in zero g). One group is designing an experiment that would utilize an aeroponic system to water the plants and use centrifugal force to clear excess water off of the plants' roots. Two experiments are using standard root growing media (spun glass basalt) with slightly different watering systems. Another group is focusing its efforts on designing an experimental ceramic micro-pump for its water circulation system. Lighting systems for all groups utilize LED panels. A Programmable Logic Controller (PLC) will serve as both experiment controller and data gatherer. During microgravity conditions aboard the Zero-G flight, data will be primarily collected by the observers, either as direct observations or by video recording. While on ISS, we will collect and record data using micro-cameras to record plant growth; various types of sensors to record temperature, CO_2 & humidity; and direct observation.

Minority Serving Institutions and Community College Students

Participating Universities – By State
** First Time Participant (institution)*

State	Institution	Page	State	Institution	Page
AL	Tuskegee University*	**22**	FL	Palm Beach State College*	**21**
CA	Citrus College*	**19**	FL	State College of Florida, Manatee-Sarasota*	**22**
CA	Fullerton College*	**20**	IN	Ivy Tech Community College of Indiana*	**20**
CA	Lake Tahoe Community College*	**21**	PR	University of Puerto Rico at Rio Piedras*	**22**
CA	Los Medanos College*	**21**	TX	University of Texas at El Paso	**23**
CO	Community College of Aurora*	**19**	WA	Tacoma Community College*	**22**
FL	Florida Agricultural & Mechanical University	**20**			

Citrus College: Glendora, California
The Impact of Viscosity on the Ability of Capillary-Driven Liquids to Spin an Axial Blade under Microgravity

Using the provided microgravity environment, we will observe the phenomena of capillary action in order to determine if axial blades may be propelled by the rising action of a liquid in capillary tubes. This idea is important to test in order to show that other means of obtaining energy in zero-gravity may be possible, such as converting the energy resulting from a fluid in capillary motion into usable work. The effect of capillary action on axial blades depends on many variables. We will investigate two of these variables: the viscosity of the liquid used and the radius of the blades. Based on our calculations, we believe that the capillary action will produce a considerable force to the axial blade, which, as a result, will be set in rotational motion. The rotation of axial blades of different radii will be compared and examined side-by-side. The capillary-driven liquids used for the experiment will be two liquids with different viscosities yet negligible difference in densities. This way, we will create a control group while focusing on the changes of a single variable, which allows us to analyze the possible factors that contribute to the powering of the axial blades. We theorize that the lower viscosity liquid is the best choice to use for the capillary liquid and the axial blade with the smaller radius will rotate at higher frequency, so it will achieve a better energy outlet. These hypotheses are based on a gravitational standpoint; therefore we believe that in a microgravity environment, our hypotheses will prove correct due to less restraint because of the absence of the gravitational force. If our experiment is successful, its results will have important applications in introducing new methods of producing reusable energy in zero-gravity which can help supply power to small electronic devices in space.

Community College of Aurora: Aurora, Colorado
Examining the Effects of Gravity on the Human Cardiovascular System and the Effectiveness of Countermeasures

Research being proposed by Team Pioneer will address the biological response to microgravity in terms of blood flow and the cardiovascular system overall. We are aware that exposure to reduced gravity conditions causes a shift in the blood of astronauts, the fluid shift to the trunk and head regions causes decreased blood flow to the legs and decreases the total amount of blood maintained in the body overall. This can cause the astronaut to lose consciousness upon re-entry to Earth's gravity, as the blood rushes into the legs and the body cannot maintain sufficient blood flow to the brain. This is a result of both the decreased amount of blood available, as well as the body's inability to constrict the veins in the legs rapidly enough. Clearly a complex problem in a biological system, we aim to construct an artificial system to simulate the vascular response to exposure to negative pressure. It is our hypothesis that if blood flow and volume can be maintained more equally to those experienced on Earth, we may decrease or eliminate the effects mentioned above. This is a concern of those in the space industry and has been addressed in many articles and studies conducted by NASA. The artificial system constructed will as closely as possible, replicate the human cardiovascular system, allowing us to define the negative pressure necessary to maintain blood flow to the lower extremities. This system will be housed in a box constructed of polycarbonate material which will be controlled and monitored by the flight team for the entirety of the flight. We believe that the data obtained from this experiment will be very beneficial as we move forward in solving this problem.

Florida Agricultural & Mechanical University: Tallahassee, Florida
Pseudo-Gravity Application for Autonomous Mobile Robot in a Microgravity Environment

Mobile robotics in space exploration is one of the scientific topics at the forefront of research in the twenty first century as the human race continues to explore the universe. The advancement of mobile robotic systems has allowed an increased ability to perform human-like tasks in environments not suited for living organisms. The improvement of the robotic systems during planetary exploration is essential to improving the quality and quantity of experiments that can be performed in space. Due to the absence of gravity during planetary exploration experiments is the obvious difference in the testing environment. This makes designing these experiments a difficult task. The lack of ability to simulate microgravity compounds the limitations to understanding the effects of the environment on robotics. There are potential hardware and software issues that can arise in microgravity that do not exist on Earth. The experiment proposed by the Florida A & M University (FAMU) Microgravity Team is intended to test the effects of microgravity on an autonomous mobile robot. A structured environment will be fabricated for the robot to perform a variety of tasks throughout the duration of the parabolic flight sequence. The robot's performance of the assigned task will be observed throughout all ranges of gravity. The effect of microgravity on the physical behavior of the mobile robot will be analyzed by comparing robot performance during different segments of the flight. A quadricopter will be attached to the mobile robot to provide a pseudo-gravitational force to the robot and aide it in performing the required tasks. The effects of the quadricopter on the autonomous robots performance will also be analyzed in this experiment. The team expects the robot to have variations in power consumption during gravitational changes. Locomotion issues may also arrive. Ideally, the robot will perform in a considerably similar manner independent of gravitational conditions.

Students from Florida A&M monitor their experiment in parabolic flight.

Fullerton College: Fullerton, California
Ferrofluid Energy Production in 1-G and Microgravity Environments

Team FFORX proposes to investigate ferrofluid behavior and its applications for energy production in a microgravity environment. Turbulent pipe flow and ferrofluid nanoparticle dipole rotation will be used to induce current in a copper wire solenoid. Present day space exploration is hindered by the limitations of solar and nuclear energy. These forms of energy limit the life span and mobility of robotic and scientific instruments currently exploring the solar system. The application of ferrofluids for energy production of space systems may provide an independent and environmentally sustainable form of energy. Ferrofluid research and mathematical models imply ideal conditions in the absence of gravity for ferrofluid energy production. Past ferrofluid research has sought to exploit the energy producing capabilities of ferrofluid nanoparticle dipole formation in the presence of magnetic fields. Team FFORX in conducting their experiment, will make use of peristaltic pumps, turbulent pipeflow, and permanent magnetic fields to induce current in a copper wire solenoid. The team will test for higher flow rate and higher induced current, as predicted in past ferrofluid research, under microgravity conditions. Conducting FFORX's experiment in a microgravity environment onboard NASA's Zero-G aircraft will contribute to past and present understanding of ferrofluid and its applications for energy production in support of space systems.

Ivy Tech Community College of Indiana: Kokomo, Indiana
Liquid Photopolymer 3D Prototyping in Microgravity

Ivy Tech Community College's Design Technology Department has devised an experiment that we believe will be beneficial to long-duration space flight and planetary colonization efforts. The experiment will include a custom stereolithography, or 3-dimensional printing, machine that will utilize fast curing gel-type liquid photopolymers to test different materials to be used to manufacture replacement parts and equipment that are potentially vital to zero-g operations. The microgravity environment for this test will be provided on a “zero-g” flight as part of NASA’s Reduced Gravity Research Program . The gel photopolymers will be cured immediately after deposition by ultraviolet visible (UVV) lighting in the range of 395-450 nm. Although liquids are troublesome in zero-g environments, the use of gel-type photopolymers will be beneficial in many ways, including: low power consumption requirements, minimal non-toxic fumes produced during the manufacturing process, no appreciable heat generated during production and the ability to produce components with both rigid and flexible mechanical properties. Testing of the machine in microgravity will include producing a variety of different patterns (tool paths) to verify the performance of the several different polymers, the ability to adhere to the supporting base material, polymer performance during an interrupted path and varying speeds of application.

Lake Tahoe Community College: South Lake Tahoe, California
Structural Integrity and Mathematical Modeling of Singular Soap Bubbles in Microgravity and Hypergravity

This study will examine the characteristics of singular soap bubbles in microgravity, including: 1. mathematical modeling of the curvature of the bubble surface in gravity, microgravity, and hypergravity, 2. video observations of color patterns, indicating variations in thickness of the soap film and the Marangoni effect, 3. structural integrity including longevity of the bubble and the region at which breakage occurs. We hypothesize that the bubble will be spherical in microgravity but may become slightly bi-catenary or elliptical in Earth’s gravity and the effect may be increased in hypergravity. We hypothesize that the bubble surface will thicken in the lower regions in gravity while the surface thickness will remain uniform in microgravity. We hypothesize that the Marangoni effect, which describes the transfer of soap film due to variations in surface tension, will be decreased or eliminated in microgravity. Finally, we hypothesize that the bubble’s upper surface will fail in Earth’s gravity and hypergravity, while the bubble will not pop or will pop at random points in microgravity.

Los Medanos College: Pittsburg, California
The Precision and Accuracy of an Electromagnetic Launching System

Research and investigation on reduced gravity opens new doors of exploration that can teach astronauts, engineers, and scientists safer aerospace systems for the betterment of our society. Our project deals with projectiles in motion. Understanding a projectile in motion can aid in the understanding of the accuracy and precision of moving bodies that are accelerated in a reduced gravitational field. Designing an apparatus consisting of parallel capacitors in series with an inductor and control switches can induce a magnetic field strong enough to project a BB towards a target. The apparatus will be projecting BB’s into a sheet of Styrofoam to be caught. With these projectiles stuck in place, a statistical analysis will show just how many of the BB’s deviated each time they were shot and it is in these results that will show just how much the environment played a role in offsetting the behavior of the BB’s. It is the measurement of the projectiles impact onto the target that can serve two purposes: first to validate the actual experiment and secondly to compare and contrast the results of varying gravity, from 0G to 2G. Does a reduced gravitational field alter the precision and accuracy of a projectile? Observation (measurement) will play a key role and will lead to inquiry and in hope will further lead to discovery of new phenomena.

Palm Beach State College: Lake Worth, Florida
Effects of Artificial Gravity on Fluid in a Reduced Gravity Environment

Chronic exposure to microgravity has been shown to cause significant bone loss in astronauts during prolonged spaceflight; this causes a problem for any extended space travel. The goal of this experiment is to show gravity like environment can be mocked with a centrifuge. A medium will be used to test the force generated by the centripetal rotation. Data will be recorded by electrical sensors to a microprocessor. This experiment will be performed in normal gravity, in microgravity, and also with centripetal force. Data collected in flight and on the ground will be analyzed post flight. Discovering a system that creates artificial gravity is essential for man’s continued space exploration and makes travel to Mars a more viable goal.

Students from Palm Beach State monitor their experiment in parabolic flight.

State College of Florida, Manatee-Sarasota: Venice, Florida
A Study of Magnetic Forces Between Dipoles During Microgravity Flights

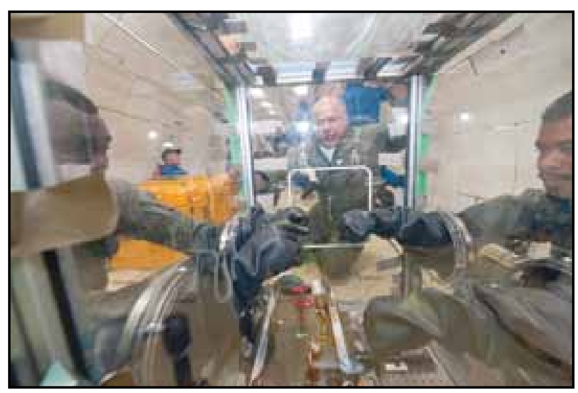
We propose to measure the force between two magnets with dipoles opposed. By using understood properties of centripetal motion, we will measure the effective acceleration of gravity as a function of the angle between the string attached to a revolving body with constant speed and the direction of effective gravity aboard the flight. We will then use this effective acceleration of gravity to determine the repulsive magnetic force between two magnets in equilibrium, since the effective "weight" of the upper magnet equals the repulsive force on it while in equilibrium. We shall plot the logarithm of this force versus the logarithm of the distance between the magnets, in order to determine whether the theoretical inverse distance-to the-fourth power dependence of the force holds for distances large compared to the size of the magnets. The video will also allow us to demonstrate to students how the force acting on the two magnets varies at each moment of the flight along with the angle of the tethered revolving body.

Tacoma Community College: Tacoma, Washington
Investigation of NAFION Membrane Wetting in Microgravity

Hydrogen-oxygen fuel cells have flown in space, but in sizes and masses that are too high for use on small spacecraft. Large electrolysis cells use high pressure to pump water through the separation membranes. While high pressure is a viable pumping method for use in micro-gravity, it is impossible to employ on CubeSat-class nanosatellites, which have a footprint of 10 cm by 10 cm. To make a practical reversible fuel cell for CubeSat operations, it is necessary to develop a microgravity water pumping method that can be packed within CubeSat dimensions. In the absence of high pressure, the behavior of NAFION membrane wetting in microgravity is an avenue worth investigating, since it potentially offers insights into how proton-exchange membranes can be hydrated simply and easily in the space environment. Our test rig uses a syringe to mechanically squeeze water into a tube which is held a few millimeters from the NAFION membrane in question. The tip of the tube is close enough for the water droplet to make contact with the membrane, even in the absence of gravity. In addition, the presence of Marangoni convection opens up new possibilities for moving water on the membranes by use of a thermal gradient. Our secondary objective is to investigate the possibility of using a thermal gradient to increase the surface area of water droplets on the membranes.

Tuskegee University: Tuskegee, Alabama
The Formation, Development and Interaction of Ring Vortices in Reduced Gravity

The formation, development and interactions of ring vortices is a phenomenon that has been studied extensively both experimentally and numerically. The flow physics of this phenomenon is of great interest because of the opportunity it provides of entrainment of the ambient fluid and effective mass and heat transfer. Study of ring vortices have been limited to in most cases of the starting vortex fluid and the quiescent fluid being the same. In some cases buoyancy effects have been also investigated. However, little work has been done due to the non-availability of environments, to decouple the effects of viscosity and gravity. This proposal intends to utilize the microgravity environment and study the effect of viscosity on the ring vortex and its interaction with the ambient fluid and other ring vortices.



Students from Tuskegee University monitor their experiment in parabolic flight.

University of Puerto Rico at Rio Piedras: San Juan, Puerto Rico
Microgravity Effect on Molecular Diffusion in Nanoporous Materials

The discussion of molecular species through nanoporous systems in microgravity conditions is of interest due to the implications of nanotechnology in aerospace technologies. The herein proposed study will provide insights on the diffusion processes in enabling technologies such as Li batteries, Fuel Cells, and nano-based wastewater purification systems. In general, the fundamental experiment to be studied is the ammonia oxidation at Pt nanoparticles/nano-supporting electrode systems. This system is currently being studied at the NASA-URC Center for Advanced Nanoscale Materials interdisciplinary research group in nanomaterials for Life Support Systems. The microgravity experiment will involve the measurement of current as a function of time at an applied potential needed for the oxidation of ammonia. The diffusional coefficient (Do) of ammonia/ammonium ion will be assessed under different supporting materials such as: Carbon Vulcan XC-72R, Carbon Nano-onions (CNO) and Carbon Nanotubes (CNT's). These materials will provide both different pore size and structure and also electronic and chemical properties that will be correlated to the diffusion of species. Due to the truly diffusional environment under micro-g conditions the diffusion of species through the nonmaterial network is expected to change and will be quantified. The electrochemical cell to be employed consists of a working electrode, an Ag quasi-reference electrode, and a Pt mesh counter electrode. The working electrode consists of an ionomer/carbon powder/Pt nanoparticle paste on the 1cm2 glassy carbon electrode. A secondary containment will be used for any possible spill. This experiment will shed light on the diffusion of ammonia/ammonium ions under microgravity conditions for state-of-the art materials currently at the frontier of science.

Students from UPR at Rio Piedras monitor their experiment in parabolic flight.

University of Texas at El Paso: El Paso, Texas
The Effect of Gravity on the Production of Structural Materials from Lunar Regolith

In-situ resource utilization is an enabling technology for future missions to the Moon, Mars, and beyond. Construction materials for landing/launching pads, radiation shielding, and other structures on the lunar/planetary surface can be produced from regolith. The project deals with the production of ceramic composites from lunar regolith simulant using combustion synthesis, also called self-propagating high-temperature synthesis (SHS). In this method, the regolith simulant is mixed with metals that can react exothermically with the simulant. Thus, upon ignition, self-sustained combustion occurs, leading to the formation of ceramic composites. This process may be affected by gravity due to the presence of liquid metal in the combustion front and natural convection in gas phase around the sample. The project will investigate the gravity effect on the combustion wave propagation and the product structure for the mixtures of lunar regolith simulant with magnesium. During parabolic flights, the mixture samples will be burned in a closed chamber filled with argon. The combustion front velocity will be measured using video recording. After the flights, the product composition and microstructure will be investigated. The obtained data will be compared with the front velocities and product structures obtained in 1-g experiments. Based on this comparison, the conclusion on the effect of gravity on the combustion of regolith/magnesium mixtures will be made.

Grant Us Space Flight Program

Participating Universities – By State
** First Time Participant (institution)*

State	Institution	Page	State	Institution	Page
AZ	University of Arizona	**27**	MI	University of Michigan	**29**
CA	California State University, Fresno*	**24**	MO	Drury University	**25**
CA	University of California, San Diego/ Grossmont College*	**27**	MO	Missouri University of Science and Technology	**26**
CO	University of Colorado at Boulder	**28**	PA	Drexel University	**24**
FL	University of Florida	**28**	PA	University of Pennsylvania*/ Rose-Hulman Institute of Technology/ Seattle Pacific University*	**30**
IL	Northwestern University*	**26**	TX	Lamar University	**25**
IL	University of Illinois at Urbana-Champaign	**28**			

California State University, Fresno: Fresno, California
Formation of Calcium Oxalate in a Microgravity Environment

Calcium oxalate is a salt crystal found in many plants and fruits such as spinach, tea, and the kiwi fruit. This salt crystal, should it be ingested in excessive amounts can prevent speech as well as induce suffocation. Calcium oxalate is also known as a kidney stone which can cause painful occurrences as it passes from the human kidney through to the urine tract. This chemical compound (calcium oxalate) accounts for 75% of all kidney stones. Lastly, calcium oxalate crystals are caused by the lack of Calcium available to bind the oxalate into a non-absorbable form in the stomach and the intestines, this change causes the oxalate to be absorbed and then excreted through the urine, raising the risk for kidney stones. Our experiments aim to investigate whether gravity has an effect on the formation and production of calcium oxalate crystals. These conclusions will be based off our current preliminary and future experimental samples on whether or not Calcium Oxalate Crystals change their molecular structure when subjected to a lack of the gravitational force. Knowledge gained from this study can aid in preventable actions for kidney stones that may possibly develop in astronauts during prolonged space missions; furthermore, our experimental studies will aid in NASA's current issues with Calcium Oxalate Crystal precipitation and filter clogging in the water waste system aboard the spacecraft. Data collected and analyzed at this stage of our research will be based on gravitational changes and crystal formation.

Drexel University: Philadelphia, Pennsylvania
Characterizing the Performance of the CubeSat Deployable Boom in Microgravity

The main objective of the experiment is to characterize the deployment behavior of a 1.5m boom for a satellite application. The boom is one of the main payloads of Drexel University's first satellite project: DragonSat-1 CubeSat. The boom is used to stabilize the satellite's attitude in such a way that one face of the satellite always points toward the Earth. This nadir pointing is necessary for ensuring that the onboard camera always points toward the target, without a complicated active control mechanism. The boom consists of an inversely rolled up tape measure with a tip mass on the end. The tape measure is designed to extend from the housing when triggered, and extend out to its full length, with the tip mass that contains small metal pellets for an added damping effect. In space environment, the boom will theoretically vibrate forever due to the shock force applied during the deployment process, which can negatively affect the satellite attitude control. By adding a damping mechanism in the form of loose metal particles to induce frictional energy loss, this vibration can be effectively damped such that the satellite can settle into a more stable attitude quickly. After preliminary mathematical analysis and some ground testing, it was determined that a full-scale microgravity testing is needed in order to accurately model the boom behavior upon deployment. Ground testing can only verify boom behavior in two-dimensional space. Any danger of the boom impacting the satellite body cannot be accurately predicted without full deployment tests in microgravity. In addition, the dynamics of the frictional energy loss mechanism of the metal pellets inside the boom tip can only be estimated and its behavior in the space environment is difficult to accurately predict. It is critical to characterize the boom deployment in a microgravity environment so that the parameters in the theoretical model can be improved for increased accuracy of the analysis.

The proposed experiment involves multiple boom deployment tests in microgravity. The test will include 4 different boom tips: empty, 25%, 50%, and 75% filled with metal pellets. The primary data will come from fixed-base deployment. Cameras will record the deployment and residual vibration/sway motion and the image data will later be analyzed to obtain the vibration magnitude and frequency data. The data analysis will verify the theoretical model and also provide insights to optimal fill-level of the damping material. In addition, if given the opportunity, free-floating deployment tests will also be conducted. One of the concerns in deploying a long boom is the potential danger of the boom tip impacting the satellite during the process. Multiple deployment tests can be conducted to qualitatively observe the possibility of 'violent deployment' events. The results of the experiment will provide the data necessary to model the damping effects of the metal particles in the boom tip, as well as qualitative data on the general behavior of the boom deployment.

A successful completion of the experiment will result in journal publications and conference presentations. All data and experimental results will be disseminated to the general public and educators through a website so that students and educators can participate in the analysis of the data, as well as learning about damping phenomenon using the online exercises that will be made available on the website.

Drury University: Springfield, Missouri
Hamiltonian Dynamics of a Two Degree of Freedom Robotic Arm with Viscoelastic Muscles in Microgravity

Students from Drury monitor their experiment in parabolic flight.

In order to improve our understanding of how the brain controls the human arm both in the presence and absence of gravity, we have developed a two-degree-of-freedom robotic arm which is driven by six servo-actuated viscoelastic muscles. These muscles represent abductor-adductor muscle pairs similar to the many such pairs that drive the human arm. Our robotic arm exhibits planar motion with two degrees of freedom about two joints. The computer-controlled servos mimic the contractive action of the sarcomeres in actual muscles, while sections of elastic tubing represent the elastic behavior of actual muscles. Motion is recorded with optical encoders built into each joint axis. Our prepared experiment is a purely feed-forward system, and our goal is to determine whether our equations of motion, when numerically integrated, will predict the observed motion of the arm within experimental uncertainties.

During the 2009-10 academic year, we developed a one-degree-of-freedom arm that also used servo-actuated viscoelastic muscles. In years past other students have done research on both one and two degree of freedom arms. In 2006 a group of students participated in the NASA Reduced Gravity Student Flight Opportunities Program, using a two-degree-of-freedom arm, but the arm was roughly machined and was only able to execute planned motions very crudely. Since then more arms have been built and experiments done at our university. More sophisticated equipment has been incorporated, and the design of these arms has improved. Our research builds on that done by those before us, but we intend to expand and refine the experiments done in the past. In particular, we plan to include accelerometers in our experiment that will measure the two components of the effective gravitational acceleration in the plane of the motion, thus allowing us to better explain the observed trajectories after the data are gathered.

Lamar University: Beaumont, Texas
Collection of Water Droplets and Mist by Electrostatic Fields

In a microgravity environment such as the space shuttle or International Space Station, free floating liquid droplets may present a serious problem due to potential interaction with electrical equipment. Because water is essential to human space travel and cannot be eliminated, it is essential to develop a mechanism by which to control the water droplets in reduced gravity conditions to reduce risk.

Students from Lamar University monitor their experiment in parabolic flight.

Due to the highly polar nature of water, it is highly influenced in an electrostatic field and is strongly attracted to an electric field gradient. This high polarity can be easily reproduced under 1-g conditions. We propose a system to produce an electrostatic field gradient that will manipulate and move water droplets to desired locations. The electric field gradient will be produced using a simple Van de Graaf electrostatic generator inserted into two sealed chambers. Water droplets of varying sizes down to a fine spray will be introduced to the sealed chambers during zero gravity intervals and will be recorded with video cameras. A water collection system will be implemented to reduce the amount of water stuck to different surfaces. This water collection system could have use in the manipulation of water droplets into containers for such re-uses as drinking and food preparation. This apparatus will additionally allow the observation of electrostatic field effect on droplets on surfaces in microgravity conditions.

Missouri University of Science and Technology:
Rolla, Missouri
Testing of a Refrigerant-Based Cold Gas Propulsion System in a Reduced Gravity Environment

With the increasing frequency of technological advancements in science and engineering, focus has shifted to changes in spaceflight that can lower the excessive cost of launching satellites and their payloads. As lower cost can be achieved with these optimized developments, spacecraft reliability can be improved with added redundancies. In order to maintain formation and proper orientation in orbit, satellite distributed space systems must be able to control their relative dynamics. The critical component to ensuring these proper attitude and orbit corrections of the satellite is the propulsion system. Certain propulsion systems, particularly onboard smaller satellites, however, are restricted by physical design constraints or safety regulations when being integrated into the design of the satellite.

One of the simplest and safest propulsion systems that exists today, and can be used as an alternative to the bulkier systems, is a cold gas propulsion system. Generally, a cold gas system uses inert, nonflammable gas propellants such as nitrogen, carbon dioxide, or xenon. Saturated liquids can be used as a possible alternative though, because they can be stored at much lower pressures which allows for smaller given volumes of storage. However, saturated liquids have not been widely used as of to date. Butane, though, has been one of the saturated liquids used, but is flammable and is therefore undesirable for student-built spacecraft. A nonflammable solution can be found in refrigerants, but have so far only been used to transfer heat in space-based systems. Further research and analysis is required in order to use refrigerants as propellants. The initial development can be attained through further analysis of the fluid, modeling the fluid system, and flying refrigerant-based systems onboard student-built university research satellites.

For the Miners in Space – Thruster team's proposed experiment, a thruster system will utilize refrigerant R-134a as the propellant within the test system and fixture. The refrigerant-based thruster test system will be mounted and tested in a sealed Lexan container aboard Zero-G's B727 aircraft, which will be used to simulate conditions that are not readily able to be reproduced in a university laboratory setting. In order to determine the effectiveness of the proposed thruster system, pressure, temperature, and thrust data will be collected as part of the design of the proposed system. The data gathered from the microgravity flight will be compared to ground testing results, and additionally may yield insight in determining the effects that propellant sloshing might have on system performance. The results of the proposed microgravity experiment will be used to aid in the integration of future cold gas systems in Missouri S&T-designed satellites, and to further the understanding of refrigerant-based cold gas propulsion systems in general. The Miners in Space - Thruster team will also share the results of their experiment with other universities that wish to pursue and develop similar thruster systems.

Northwestern University: Evanston, Illinois
Cathode Surface Geometry as a Factor in Electrolysis in Microgravity

Electrolysis has countless applications for life support (Linne), propulsion (Groot), and fuel cell (Bents) systems in microgravity which are applicable for use both currently on the International Space Station (ISS) and in future long-term missions. The primary impeding factor in electrolysis efficiency is bubble accumulation on the electrodes, which insulates a fraction of the surface and hinders electrolysis performance (Vogt). Developing methods for minimizing bubble accumulation on the cathode by encouraging bubble migration along the surface is therefore of utmost importance in optimizing electrolysis efficiency. In addition, previous experiments have demonstrated a direct correlation between electrolysis efficiency and the fraction of bubble coverage on the surface of the cathode (Vogt). Data gathered on factors affecting electrolysis productivity is thus not limited to strictly electrolysis applications and could potentially be used to aide in the design of all systems for which productivity is a direct function of bubble surface area coverage (including boiling flow heat transfer systems and packed bed reactors).

Students from Northwestern University monitor their experiment in parabolic flight.

In a microgravity environment, the absence of buoyancy makes micro-convection the dominant force in the process of bubble nucleation, growth, and departure. This has a major impact on the accumulation of H2 gas bubbles on the cathode surface during electrolysis (Straub). Past studies have explored various external methods for clearing gas bubble accumulation from the cathode surface, but little work has examined the impact of properties of the cathode itself. The goal of this experiment is to determine the relationship between cathode surface geometry and bubble accumulation behavior, specifically bubble surface area coverage over time. The experiment will study the bubble surface coverage over time as quantified by ohmic resistance measurements for a suite of five cathode geometries undergoing electrolysis in microgravity.

University of Arizona: Tucson, Arizona
Analysis of Gravitational Effects on Liquid Lenses (ANGEL)

With an increase in the need for fast and reliable variable-focus optics, extensive research has been conducted with regard to liquid lenses. Many different methods have been developed to create a variable-focus liquid lens, with most relying on fluid pressure differentials and electrochemical effects to induce curvature in a liquid-liquid interface. Methods that utilize fluid pressure include: aperture adjustment, mechanical actuators, stimuli-responsive hydrogels, and mechanical-wetting. Previous attempts at creating liquid lenses have relied on small apertures to lessen the effect of gravity. By testing a mechanical-wetting liquid lens in microgravity, the aperture can easily be increased by an order of magnitude. Using a large-aperture (30 mm) mechanical-wetting liquid lens, imaging and surface characteristic tests will be conducted using a variety of fluid combinations. The Software Configurable Optical Test System (SCOTS) method will be utilized to test the effect of microgravity, standard gravity, as well as hypergravity on the lens. The liquid lens will be characterized in all three scenarios to gain an understanding of aberrations under varying gravity conditions.

University of Arizona: Tucson, Arizona
Organic Compound Synthesis in Extraterrestrial Conditions

This experiment will explore how the production of amino acids from inorganic gasses is affected by rapidly changing gravity. The formation of amino acids from basic gasses was explored most famously by Stanley Miller in 1953, but recent findings have shown that these amino acids and their equivalents can form in very hostile environments, such as on comets. This experiment will lessen the gap between laboratory conditions and the actual conditions of space by performing the same basic experiment from 1953 with a new variable: changing gravity, as might apply to a comet or small planet. The results from the microgravity flight will be compared to the results achieved in the same amount of time in normal gravity; various qualitative and quantitative chromatographic methods will be employed to both separate and characterize the results. From this comparison, it will be possible to determine what, if any, effect gravity has on the formation of amino acids from inorganic reagents.

University of California, San Diego: San Diego, California and
Grossmont College: El Cajon, California
Intracranial Pressure in Microgravity

The cephalic fluid shift experienced by humans in microgravity has caused numerous headaches for both the humans who have traveled into space and for the scientists trying to understand the mechanisms involved, particularly in regard to the effects on intracranial pressure (ICP). Current understanding suggests all astronauts are at risk of elevated pressures and swelling in the eyes as a probable result of intracranial hypertension and some degree of anatomical susceptibility, which can result in permanent vision impairment. Despite the numerous health challenges associated with fluid shifts in microgravity, all of the physiological mechanisms responsible are not completely understood. 6º head down tilt (HDT) is used as a bedrest analog to long-duration spaceflight, but the effects on intracranial pressure are not as marked. The difficulty of noninvasive measurement and small number of research opportunities presents challenges to understanding the dynamic circulatory changes that occur in reduced gravity, and their effect on ICP. Additionally, the flow characteristics of viscoelastic fluids (e.g. blood) through collapsible tubes (e.g veins) are unintuitive. For these reasons we propose to construct a model that will represent major features, pressures and flows of the cephalic and cranial circulation, and to empirically test fluid shift and ICP hypotheses in microgravity aboard a parabolic flight. Results will be compared to the same experiment performed in 1G standing upright, supine, and in 6ºhead down tilt (HDT). Additional angles will also be tested so that post-flight we can determine, based on the model, what angle of head down tilt best reproduces the intracranial pressures measured in microgravity. Between flights, "brain tissue" volume will be decreased to correspond to the average age-related atrophy expected between the youngest astronaut to ever fly, Sally Ride (32), and the oldest, John Glenn (77), which we expect to see as protective.

University of Colorado at Boulder: Boulder, Colorado
ALL-STAR Microgravity Structural Deployment and Attitude Control Test

ALL-STAR is a low-cost 3U CubeSat bus capable of supporting the 1 year on-orbit operation of a variety of space-based research payloads that can be configured and ready for flight in 6 months through a simplified payload hardware and software interface. CubeSats are a standard size and shape of picosatellites that measure 10 cm by 10 cm by 10 cm for every 1U. These satellites are then launched on any rocket as a secondary payload in the Poly Picosatellite Orbital Deployer (P-POD). Once in space, after being ejected from the P-POD, the ALL-STAR satellite will deploy an external shell and solar panel wings to increase the surface area available for solar panels. The deployment mechanism is being designed and manufactured by students on the ALL-STAR team and has never been tested in a microgravity environment. In addition to needing to test the deployment system, the ALL-STAR students are also designing and manufacturing a micro Attitude Determination and Control System (ACS). This system includes reaction wheels to control attitude. These wheels can only be tested in one degree of freedom at a time on the ground. By flying with NASA's National Space Grant Program, "Grant Us Space", the ALL-STAR team can verify a portion of their requirements for operating in the space environment and increase their Technology Readiness Level. This document outlines the benefits of this test as well as an outline of procedures for the tests.

University of Florida: Gainesville, Florida
Chilldown Process of Cryogenic Transport Lines in Reduced Gravity

Cryogenic fluids are utilized in the thermal management, power, propulsion, and life support systems of spacecraft. The transport of such fluids requires the cryogenic transport line be initially chilled down. The objectives for this experiment are to compare the chilldown rates and flow patterns between the tests performed in Earth's gravity and reduced gravity conditions. For a fixed length of piping and same pipe diameter, the chilldown rate will be less in reduced gravity conditions than in terrestrial conditions. The cryogenic fluid will assume a stratified flow pattern in Earth's gravity and an annular flow pattern in reduced gravity. Ground based laboratory test results will provide a set of control data and reduced gravity results will be obtained aboard NASA's C-9B aircraft. The independent variables are tube radius and mass flow rate. This experiment will visually record the flow pattern through a test section of tubing, and measure the temperature profile in order to determine the pipe chilldown rate.

University of Illinois at Urbana-Champaign: Urbana, Illinois
Space Parasites: Exploring Nematode Behavior in Reduced Gravity Environments

Many nematodes species, including Meloidogyne spp., Ditylenchus destructor and Ditylenchus dipsaci, infect the crop plant Solanum tuberosum, commonly known as the potato plant. If humans are to build greenhouses in space, this popular vegetable may be one of the crop plants used to sustain human activities on Lunar or Martian bases. On Earth, some nematodes use geotaxis to infect plants which lead to decreased yields. On a lunar or Martian colony, such a result may prove to be fatal if astronauts come to rely solely on plants for food and oxygen replenishment. Current methods of sterilizing the agricultural soils to eliminate nematodes may not be practical in an outer space setting: sterilization methods also destroy helpful organisms responsible for nutrient cycling within the soil and nematode eggs have been known to survive sterilization processes. Furthermore, introduction of chemicals meant to kill nematodes may prove to be deleterious to the health of astronauts through bioaccumulation in the artificial environment.

In the absence of gravity, we hypothesize that other environmental cues will be utilized by nematodes to locate their host plants. Specifically, the electrical field should attract the nematodes most efficiently. The goal of the proposed project is to gather data on the behavior of the nematodes in varying environmental conditions (pH, temperature, electrical and magnetic fields) and to determine which physical parameter could attract the nematodes away from plants. Given our hypothesis, we predict that nematodes will congregate near the sources of the electric field.

University of Michigan: Ann Arbor, Michigan
Autonomous Boom CubeSat Deployment Experiment: ABCDE

Autonomous Boom CubeSat Deployment Experiment (ABCDE) is a newly proposed microgravity project from the GPS Occultation Tomographer & High Accuracy Magnetometer (GOTHAM) Boom team at the University of Michigan (U of M). GOTHAM Boom is researching the deployment of a coilable boom on a 3U CubeSat structure. A CubeSat is a nano-satellite platform developed and standardized by California Polytechnic State University and Stanford University (California Polytechnic State University). A 'U' refers to the size of the CubeSat. Each 'U' is 3.94-inches x 3.94-inches x 3.94-inches (10cm x 10cm x 10cm). The GOTHAM CubeSat is to be developed into a space weather mission at the University of Michigan. It will use a magnetometer on the end of an extendable boom to measure magnetic field-aligned currents and ultra-low frequency waves in the ionosphere. The boom design will be shared for use in future University of Michigan CubeSat missions. To continue with this mission, the team needs to test the deployment of the boom in microgravity. Microgravity gives the payload six degrees of freedom, similar to a space environment, and lets the team perform tests not possible in Earth's gravity. Dynamic characteristics of the boom need to be determined and modeled precisely to account for variations in data gathered by the magnetometer. This needs to be done in zero-g in order to get a testing environment as close as possible to space environment.

The boom is a key component in the CubeSat for GOTHAM because it is needed to hold the magnetometer away from electromagnetic noise generated by the CubeSat bus. ABCDE is intended to verify the boom deployment design and understand the dynamics in a microgravity environment. For the experiment, the CubeSat structure (defined as 'payload') spins at differing rates and about multiple axes, releases in microgravity, and then deploys the boom. Instead of a magnetometer, an IMU at the end of the boom measures the operational dynamics. The sensor data are synchronized with video camera footage to aid analysis.

The data analysis will help the team improve upon the current design, which will increase the CubeSat project's TRL. Demonstrating the current design works or improving upon it will allow the team to continue the project into the final GOTHAM project.

University of Pennsylvania: Philadelphia, Pennsylvania,
Rose-Hulman Institute of Technology: Terre Haute, Indiana and
Seattle Pacific University: Seattle, Washington

Granular Impact Cratering in Microgravity and Hypergravity

Unlike the physics of fluids and solids, granular mechanics are not well understood. Predictions of granular response to applied forces have proven unreliable. In terrestrial gravity, lowspeed impact cratering is a simple way to understand the effects of these forces, and has been used to mimic geophysical events. In previous experiments, depth of craters formed by projectile impact are used to analyze granular dissipation mechanics, as crater depth relates to the force exerted by the medium onto the projectile. Two different equations have been generated from observations to describe the stopping force and penetration depth, one dependent on gravity and one independent of gravity, respectively. While both equations describe observations from experiments, they cannot simultaneously be correct, as one equation cannot be derived from the other. We propose to conduct these same experiments in varied levels of gravity to test whether or not the current observational equations hold true. Specifically, we propose to measure the depths of craters formed by projectile impact of spheres of varied densities and diameters from a range of drop heights and at varied accelerations of gravity. By investigating granular mechanics in reduced gravity conditions, and comparing our results with those acquired in the laboratory, we will determine the nature of the stopping force and the role of gravity in setting the resistance of the sand to penetration. If the current equation for penetration depth is correct, then the penetration depth measured in microgravity should be independent of g. The results of our experiment should reveal the importance of gravity in granular mechanics. As granular materials are simultaneously ubiquitous and problematic in everyday life and industry, probing the nature of granular fundamental forces will provide very practical and useful insight.

Students from University of Pennsylvania monitor their experiment in parabolic flight.

Teaching From Space Flight Program – By State

** First Time Participant (institution)*

All Saints' Episcopal School: Fort Worth, Texas
Boiling Without Pressure in Microgravity

One team member, Marsha Johnson, had worked with NASA in April of 2000 on a bioreactor design to enable the removal of bubbles which form during tissue culture. This experience of working with gas/liquid interfaces led to thinking about other processes where bubbles form in liquids. Boiling is such an interesting phenomenon, involving pressure, temperature, specific heat and intermolecular forces of attraction, that it seemed a natural for an investigation. Further, everyone on the team agreed that the gas/liquid interface studies are even more interesting in microgravity. Ultimately, the group decided to merge these two concepts into one project.

There are several concepts being tested. The first is that density differences are apparent in a 1-g environment, but disappear in a 0-g environment. In a 1-g environment, when a liquid boils, the gaseous phase rises to the surface of the liquid due to its lower density. This should not happen in microgravity, but what exactly does happen to the gaseous phase? Does it remain interspersed within the liquid phase? Do gas bubbles form within the liquid and remain? The basic question is: when a liquid boils in microgravity, how does the gaseous phase behave? Observing this behavior will contribute to being able to understand the mechanics of the behavior; this understanding can potentially contribute to scientific research towards the development of complex systems such as power plants and cooling systems in microgravity and on earth, where boiling liquid plays a key role.

Another concept to be observed involves the effect of pressure on the surface of a liquid. It was the team's consensus that trying to test the phenomenon of boiling with heat is too time-consuming for a short spurt of microgravity. Boiling can be induced by reducing pressure rather than by increasing temperature, and this could be done quickly. A 0-g environment will not have an effect on this portion of the experiment as it is independent of gravitational force.

While performing this experiment in 1-g, we have noticed that most of the bubbles form on the surface of the water in the flask, with a few forming along the sides of the flask, as opposed to forming on the bottom of the flask when heat is used to induce boiling. This may actually provide an even more interesting study than first thought. Will vapor bubbles which form on the surface remain within the liquid at all? Will the bubbles forming on the sides of the flask coalesce to form one large bubble within the liquid? Observing and understanding the behavior of the bubbles is the goal of this experiment.

Lastly, we are interested to see if the bubbles formed will move within the liquid or remain where they form. One would expect them to fall at the same rate as the water itself in free fall, but other forces besides gravity may be at play. This is another behavioral characteristic of the gaseous phase of boiling liquid that we want to observe and understand as a result of this experiment.

By simulating conditions under which water can boil, and exposing the simulation to microgravity, we can observe the behavior of the gaseous phase of boiling water in microgravity; and through observation, we can try to understand the mechanics of the behavior.

We believe the gaseous phase will coalesce to form one large bubble close to the surface of the liquid, and that it will move toward one side of the flask, coming into contact with the glass.

Our observations could lead us to more questions to be answered, which could lead to further experimentation, but the goal is to see and understand the behavior of the gaseous phase. This will serve to inspire learning and understanding of natural and scientific processes within the classroom. Also, having the ability to observe this behavior, and record it on video, gives us the ability to not only visually document our experiment and research, but also gives us the ability to share it. Making our recorded observations publicly available could potentially further and expand the understanding of boiling liquids in the scientific community.

Bergen County Technical Schools: Paramus, New Jersey
Helium Balloon Buoyancy in Microgravity

Can a positive buoyancy balloon and payload, like the one used with our High School Project Aether launch in April 2011, be used to explore other planets and moons? During the NASA microgravity flight, the Bergen County Technical School flight team will measure changes helium balloon buoyancy as a function of gravity for several helium-air mixtures, in addition to a Xenon filled balloon. An experiment rig was constructed and the balloon buoyancy forces were measured in 1-G. It is anticipated that with the exception of a Xenon filled balloon, all of our balloons will experience significant changes in buoyancy as a function of gravity level. The implications of our results could yield information that could be used to design further experiments in the unmanned exploration of other planets and moons with significant atmospheres. We look forward to sharing our findings with our fellow teams and NASA hosts during our Flight Week presentation.

Bob Jones High School: Madison, Alabama
3D Printing in Microgravity

As NASA continues its exploration of space, the Moon waits for humans to return, while Mars has yet to have that first step of man upon it. Equipment to support the astronauts will be built as robust as possible, but there will be the likely need for replacement parts. One of the ways of doing this on Earth involves a 3D printer (also known as a rapid prototype machine). Anyone, given the right file and dimensions, can print any part in plastic to replace a broken or faulty one. When far from home in space or on an “alien” world, the ability to print a replacement part could be the difference between life and death. The question to answer is: can a 3D printer work properly in a reduced gravity environment?

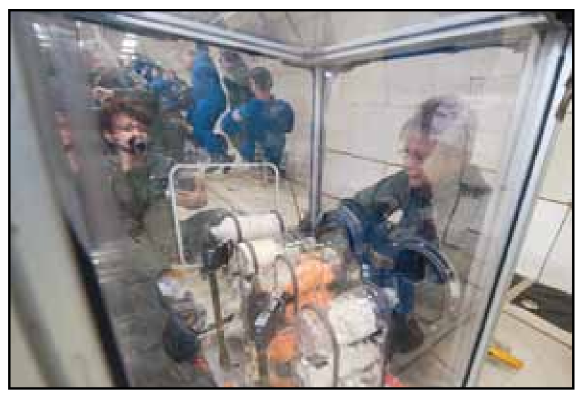
To answer the question whether a 3D printer will work in reduced gravity, our team (comprised of students and faculty) will design, construct, test, and “fly” a small 3D printer. The printer will print a test part on Earth at 1g, then print the same part in reduced gravity. The team will contrast and compare the two parts to see the tolerance levels between them. For more simple parts, we expect a close comparison, but other more detailed parts may not print as desired. No printed or digital article could be found to show this experiment having been completed, so we believe to be the first of its kind. Our hope is that our findings will move NASA or private industry forward and actually launch a 3D printer into space.

Boston University Academy: Boston, Massachusetts
Overclocking a Pendulum

A common high school physics experiment is to have students explore the effects that different variables, such as mass and length, will have on the period of a simple pendulum. Although the period of a pendulum also depends on the acceleration due to gravity, changing this variable is not easily accomplished in the classroom. By setting a pendulum in motion at various gravitational accelerations on a Reduced Gravity Education Flight, one can obtain a set of data for students to verify the theoretical dependence of the period of a pendulum on gravity. Both a string pendulum and a rigid rod pendulum with bearings will be utilized in this experiment. A Vernier Wireless Dynamic Sensor System will be used as a pendulum bob to obtain string tension and acceleration data during the flight. The information recorded by the dynamic sensor system will provide students with more detailed data for more in-depth analysis of the pendulum dynamics. By obtaining video footage of the experiment with accompanying measurements of acceleration and tension, students in the classroom can use image analysis to verify a standard textbook relationship, or even derive the relationship by observing the video footage.

Central Florida Aerospace Academy of Kathleen High School: Lakeland, Florida
The Ups & Downs with Colloids

The five polyurethane polymer colloids, when sprayed in a microgravity environment will maintain a uniform spherical shape in the 2 liter plastic bottles due to the equal pressure exerted on the suspension on all sides given the free fall nature of the parabolic flight. The high gravity 2G portion of the flight will force the suspension to one side of the container allowing it to adhere to the bottle if it still is in the semi liquid state and has not yet began to harden during the time between the two portions of the flight. Although the polymer colloidal can be used as insulation and to fill gaps in a "normal gravity" environment, this same suspension will not spread to fill gaps or insulate the bottle due to the lack of gravitational pull. The students believe all polymer colloids will react the same under the conditions in micro gravity despite the chemical differences. In order to test this hypothesis, the team will test the following colloids provided by DOW Chemical Great Stuff Big Gap, Fire Block, Gaps and Cracks, Pond and Stone, and Window and Walls by spraying the foam into clear two liter bottles for a set duration of time and observing/videotaping the reaction of each in both the microgravity and heavy gravity environments. The bottles will be covered at the back with graph paper in order to create a measurable grid for assessing the expansion and adhesion of the products. All five bottles will be videotaped throughout the entire flight for quantitative comparison with the laboratory established controls. Each of the colloids will be tested and followed through thirty-two parabolic arcs, lunar gravity and Martian gravity environments during the two flights. Poly urethane colloids have a distinct advantage over the "open cell" latex foams that can absorb water. The closed celled poly urethane foams expand to fill a greater area and are extremely efficient at creating a water resistant barriers and serving as ideal air sealants. The greater application of this project is the use of such poly urethane colloids on future space transportation systems and the creation of lunar and Martian base camps.



Educators from Central Florida Aerospace Academy monitor their experiment in parabolic flight.

Clear Lake Intermediate School: Clear Lake City, Texas
Acceleration in Reduced Gravity

This experiment is being flown as part of the Teaching From Space Program, a NASA effort to provide teachers with unique, real life, STEM experiences and knowledge that would inspire students to pursue careers in aerospace. The experiment was designed by the staff and students at Clear Lake Intermediate School, located minutes from NASA in the Houston-Clear Lake area. Our student experiment will be flown on the Zero G aircraft by the student's actual classroom teachers and a NASA mentor. The purpose of involving students in the Reduced Gravity Program is to allow them to make hypotheses about how gravity affects Newton's Laws of Motion. Students from math, science, and technology career classes will have a chance to see teachers test student hypothesis using scientific research in a real laboratory setting where results cannot be easily predicted. By experiencing the process of the scientific method from the view point of several disciplines (science, math, and engineering) students and teachers will gain insight into how science is really done by researchers in the field. Through this multidisciplinary approach, students will see the real world applications of concepts taught in class. Teachers will develop collaborative working partnerships that will drive curriculum design for years to come.

This experiment will test the effects of differing gravitational environments on the acceleration of a toy car traveling on a metal track. Newton's law states that the combined forces acting on an object will affect the objects acceleration. Acceleration is the change in an object's velocity over time. When force acts on an object, the object will accelerate. This experiment will test how changing gravitational environments affect the initial rate of acceleration of a toy car on a ramp. We expect the car's initial acceleration to be smaller when stronger gravitational forces are acting on it and expect the car to accelerate at a faster rate in the near zero gravity environment.

Elgin Public Schools: Elgin, Oklahoma
Stimulant/Depressant Effects on Daphnia

Our team of elementary, middle school and high school teachers met together to determine an investigation that we could use that would be something of interest to our students and community, and be relatively easy to use in class with our students. The idea for this activity came from a biology activity testing the effects of alcohol and coffee on the heartbeat of a daphnia. We thought to extend that to the energy drinks our middle school and high school students are consuming in such great quantities these days and nicotine and alcohol to coordinate with our DARE program.

The experiment will study the effects of commonly used substances on the physiology of simple (daphnia) and complex (human) systems; the affects of nicotine, alcohol, caffeine and popular energy drinks on heart rate in 0g, 2g and 1g environments. We want to show the effects of microgravity and 2g on the heart rates of simple invertebrates, to build interest toward an examination of how humans, plants and animals will need to adapt during a long-term space flight to Mars. We will compare the results obtained by our students on the ground to those we obtain during our flights, to see what, if any, affect microgravity and 2g have on the heart rates of daphnias exposed to stimulants or depressants, and continue with research on the already known effects of space flight on human body systems and the efforts to understand and mitigate those effects.

Glenbrook North High School: Northbrook, Illinois
Magnetic Fields

This experiment is designed to study the behavior of magnetic dipoles under microgravity conditions. Magnetic spheres will be released in pairs of 2, 4, 6, and 8 magnets to observe their movements and interactions. Movement comparison and interactions will be studied and a model will be created. Sherical magnets have a uniform and symmetric dipolar field and because of this, are easier to analyze and construct models from. While magnetic properties and magnetic dipole studies have been researched separately in gravity, few have been performed in combination in microgravity. This experiment set compares flight and drop tower results with ground-based results, and aims to develop a qualitative and quantitative model of magnetic bonding behavior in microgravity. Studying the behavior of spherical magnetic dipoles and their effect on each other will be the over-riding purpose addressed by this experiment set.

Highland Park Middle School: Dallas, Texas
Mentos and Diet Coke

The purpose of the experiment is to measure the amount of gas pressure produced and reaction time when mixing 3 Mentos with 500mL of Diet Coke in zero gravity environment and compare it with our identical ground lab results. Does zero gravity have an effect on the amount of pressure and/or time of the reaction?

An apparatus has been created to isolate the substances and force the Diet Coke to react with the Mentos within a zero gravity environment. The main apparatus will be constructed prior to the arrival to Houston. There will need some night before preparation of the Mentos and sealing the Diet Coke bottle to the apparatus.

The night prior to experiment: Place 3 Mentos into the ball valve and lock them inside. Coat the outside of the 3/4" barb with fast setting epoxy. Then quickly opening the 500ml bottle of Diet Coke (1-2 seconds) as not to let much of the carbon dioxide escape. The epoxy will make a tight seal to the inside of the bottle. A coating of epoxy will be used on the outside contact points of the 3/4" barb and opening of Diet Coke bottle. Typical curing times for epoxy are 4 hours.

The experiment: Once we reach the Zero Gravity threshold, one person will open the ball valve disengaging the 3 Mentos while another person will squeeze the 500ml of Diet Coke into the ball valve thus forcing the Diet Coke into the Mentos. In our classroom, the Mentos simply fall into the Diet Coke bottle, but with Zero Gravity it is important that we are forcing the Diet Coke into the Mentos. We will be measuring maximum pressure reached and for how long did the reaction last. The HD Flips video cameras will be used to record the pressure gauge to accurately be able to playback and find peak pressure and track reaction time. We are planning to do 23 trials for comparison to our ground results.

Comparing results: The videotaping of the pressure gauge will be key. This will allow us to make a plot curve of each reaction comparing each second of reaction to the amount of PSI. The figure below shows an example of on our ground trials. After several trials, we will have an "average" reaction curve to compare to our ground data curve.

Lake Oswego Junior High and High School: Lake Oswego, Oregon
Chillin' at 0g's

This experiment is being flown to provide an opportunity to collect cooling rate data on a copper plate at both 0 and 2 g's. Many types of electronic equipment (TV's, computer monitors, stereo amplifiers, electrical power) rely on passive convective cooling to reduce operating temperatures. Often these devices rely on heat sinks composed of a metal base with fins attached to increase surface area. Heat is dissipated as it rises off the fin material due to convection currents. We are interested in investigating what effect 0 and 2 g will have on the cooling rates and patterns on a single copper fin.

In this experiment, we will be capturing thermal images of a copper plate as it cools over the course of 20 seconds. A 32 gauge copper plate painted flat black will be heated to approximately 125ºF with a 32 gauge Nichrome wire attached to the back of the plate, this will take approximately 20 seconds. At the beginning of the 0 g phase of the flight, the heating unit will be turned off and the plate allowed to cool for the remainder of the 0 g phase. While cooling, thermal images will be captured every 5 seconds. The first image will be captured immediately before shutting off the heating unit. The final image will be captured when the 0 g phase ends. The images will later be analyzed to determine temperate change over the course of the experiment and cooling patterns on the surface of the plate. This procedure will be repeated in 2 g environment and on the ground at 1 g. We hope to run at least 10 trials in all 3 gravitational environments.

LiftOff Alumni: Texas
Systematic Planet Creation Experiment (SPACE)

This team is associated with the Texas Space Grant Consortium in Austin, Texas.

By using various materials representing the ingredients found during the formation of the solar system, we will model the accretion theory. We will place materials individually in Petri Dishes and also combine several ingredients in Petri Dishes to simulate the solar system formation. The Petri Dishes will be placed on two round plates – one will be spun by hand and the other with a NXT robot motor. By utilizing two methods we will observe whether the speed at which the samples spin makes a difference in the way the materials accrete. We will use a one Tablespoon sample of the following materials in the Petri Dishes:

We will put a ¼" inch layer of water in each Petri dish and freeze ahead of time. We will then sprinkle the material on top and seal the Petri dish. If a reaction may occur prior to melting between the frozen water and the material, we will place a layer of wax paper between the frozen water and the material. We plan to seal with biological paraffin followed by Petri sealing tape. The Petri dish will be mounted with the material down and frozen section above so when the frozen water melts the reaction will occur.

Using one Lazy Susan (round tray with ball bearings) and a motorized NXT robot with a 10 " plastic tray on top, we will place three Petri dishes on each tray and use heavy duty Velcro to hold in place. One Lazy Susan will sit on top of an NXT motorized robot to spin and the second Lazy Susan will be hand-spun. This way we can test whether the rotation speed is a factor in accretion. We will place long strips of heavy duty Velcro inside the floor of the glove box beside each Lazy Susan tray. All Petri dishes will be inside the glove box on the Velcro. The first two parabolas we will film the Petri dishes (no spinning). During the 1 or 2g portions of the flight, we will then reach in, using the glove box, to spin the Petri dishes. Two cameras will be mounted on the top of the glove box, face down, and film constantly. We will fly 2 parabolas with no spinning of the material, use 2 g portion to spin containers and fly 6 parabolas observing the materials. We expect it will take 10 total parabolas for each set. During the 2g portion of the flight we will exchange the Petri Dishes on the Lazy Susan and plastic tray with the ones on Velcro on strips inside the box and repeat the process. We will show what happens to the materials in the glove box (particles in the solar system) and what happens when rotation occurs.

Marble Falls Independent School District: Marble Falls, Texas
Maintaining Proper DO Level

Having fresh fish aboard a long-duration space flight could be a real morale boost to astronauts, and could contribute to both their physical and mental health. The focus of the experiment is to test the ability to maintain the proper diffusion/solution rate of oxygen in water for sustaining a high-density hybrid Tilapia population in microgravity conditions. A 2-molar solution of sodium sulfite will be injected into the water to strip oxygen and simulate the routine metabolic rate (RMR) that the hypothetical tilapia would have. The water will be circulated through the closed system by a water pump at a rate of 0.05 gallons per minute, and pure oxygen will be injected into the water column through a diffuser at a rate of 0.04 cubic feet per minute. Flow rate of both water and oxygen, as well as the dissolved oxygen (DO) and water temperature will be continuously monitored. The data collected during the reduced gravity flight will be compared to data collected on the ground, and is expected to prove that aquaculture and the extended concept of aquaponics are feasible in microgravity conditions. Our team plans to enlist student help in analyzing the data, proposing possible applications of the data, and disseminating the results of the experiment.

Educators from Marble Falls ISD explain their experiment to the TRR committee.

The Master's Academy: Oviedo, Florida
Chemical Reactions in a Reduced Gravitational Field

This experiment is being flown as part of the NASA Reduced Gravity Education Flight Program. The participating teachers from The Master's Academy intend to perform an experiment in reduced gravity related to the subject matter of their students, who have been investigating volcanic eruptions, the gases emitted during an eruption and the formation of land masses. The students experimented with homemade volcanoes, observing the chemical reaction between baking soda and vinegar. A similar experiment will be conducted by the teachers on the Boeing 727 reduced gravity aircraft to illustrate the differences between a chemical reaction in an Earth gravitational field (1-G) and a reduced gravitational field. Both the middle school students and their teachers will gain invaluable insight into performing experimental design, understanding the scientific method, testing operations, and public education. Additionally, this experiment will inspire the students to pursue careers and education in the science, technology, engineering and mathematics (STEM) fields.

Miami Dade County Public Schools: North Miami Beach, Florida
Worms in Space

This is an experiment to determine whether or not corn ear worms, useful members of an ecosystem, could survive a space flight, with the purpose of being utilized in some capacity in an interplanetary colony. The question being explored here is the effect of zero gravity on the pupation rate of corn ear worm larvae and pupae. The larvae and pupae will be flown on two flights in the Reduced Gravity Program. They will be observed after the flight and compared to a ground-based control group.

Midway Independent School District: Waco, Texas
The Amazing, Floating, Flying Air Pellets

The “Amazing, Floating, Flying Air Pellets” is being flown to establish what effect gravity has on the dispersement of airborne particles. The results will be correlated to establish how flammable materials may move in a microgravity environment, such as the space station, in order to establish procedures that may be used for fire prevention and containment. The particle cloud formed during the experiment will act as a representation of the flame that would be produced in these same conditions. This experiment may provide future researchers with information that will help with the testing of fire extinguishing equipment. The results of the experiment conducted in microgravity will be compared with results achieved in an Earth-gravity environment to determine if materials used for extinguishing fires on Earth may be used in the microgravity environment of space. It is believed that the absence of gravity will allow the air particles to disperse more freely, creating a larger cloud or flame than in an Earth gravity environment.

Mountview Road School: Morris Plains, New Jersey
Magnets in Space

Our team will bring student tested magnets and washers onboard the aircraft along with a plastic cylinder holding the stacked washers in a single column. We will test the magnet’s ability to lift the washers in two levels of gravity, hyper-g, and reduced g. (Our students will have tested the magnet in 1g). All experiment materials will be placed in the RGO-provide glove box. The box will be secured to ensure no pieces leave the box. During hyper-gravity the magnet will be placed on top of the open end of the tube. The tube will be pre-packed with 20 color coded washers. The tube will be turned upside down to establish a strong contact between washers and magnet, then turned right side up once again. A team member will slowly remove the cylinder. Another team member will add additional washers, one at a time, until the maximum load is achieved. This will determine the “lift” power of the magnet during hyper-gravity.

The procedure changes a bit for zero g. The cylinder, washers and magnet remain the same. The magnet is again placed on the open end of the tube. During acceleration, the tube is held upside down to establish strong contact with the magnet. As reduced g is achieved, the orientation of the tube will not matter, but care must be taken when removing the magnet with the washers to separate the attracted washers from those that are just floating within the cylinder nearby. The washers which remain attached to the magnet will be counted to determine the “lift” strength of the magnet during reduced g.

In addition to testing a magnet’s ability to lift weight, we will also test the force field around a magnet. To do so, we will insert a magnet into an enclosed BB filled container and count the number of attached BBs in two levels of gravity, hyper-g, and reduced g. (again, our students will have conducted this test in 1g). To contain the BBs during reduced g an elongated plastic bag will be used as a container lid. The magnet will be inserted into the BB container through the plastic bag. When the magnet is extruded , the bag will be tied off enclosing the magnet and BBs.

Nederland Independent School District: Nederland, Texas
Separating Liquids in Reduced Gravity

During long term space travel, there will be an accumulation of liquids of various densities: some that can be recycled, and some that cannot be recycled. We will observe the dynamics of liquids in 1g, recording by video the interactions of liquids in stationary and rotating clear cylinders. With the introduction of different gravities from 0g to 2g we will observe, record, compare, and contrast the behavior of the liquids. The question is, then: will they mix or remain separate? This experiment explores the possibility of recycling important and necessary liquids, such as water. How can these liquids be separated in a microgravity environment? If some liquids can be separated and recycled, that would reduce the weight and cost at launch.

In a gravitational field, liquids of different densities separate on their own. This makes it easy to recycle an essential and necessary liquid, such as water. Our proposed solution is to introduce a rotation of 10 RPM to determine if an artificial gravity can be achieved, thus allowing the separation and recycling of the liquids. After necessary research and design, a method of recycling of liquids can be developed, thus reducing weight and cost at launch. This allows for: more crew members, research projects, housing, fuel and power supply, and food sources.

Ocean Breeze and Surfside Elementary: Indian Harbour Beach, Florida
Gravity and Magnets: Forces Explored

Investigation #1 deals with magnetic force and how it might be affected by gravity.
We will use a simple magnet wand and test the amount of mass that can be held in place at 1G (in the classrooms before flying) to act as a control, at microgravity (0G) and at hypergravity (2G). During flight, the same magnet will be used to test the amount of mass that can be held during microgravity and hypergravity, multiple trials at both will be conducted. We will have various and incremental mass (metal) units available for quick testing, to determine the amount of mass the magnet can hold. This will be determined by applying the mass to the magnet, recording the last mass amount that was able to stick to the magnet before the next incremental size did not stick. Upon completion of the flights and all testing, the data from each will be compared and conclusions made.

Investigation #2 will test the affect of gravity on the speed of a ball bearing launched in a magnetic accelerator. Our students believe that the momentum will change during 0G and 2G and as Momentum = (mass)(velocity), if the mass is constant and the speed changes, then the momentum changes, as the direction will not change. Our accelerator can be viewed in the Equipment Description section of this document. It will have a single ball bearing on one side of a strong magnet and 3 more lined up on the other side. The distance from the magnet, that the single ball bearing is released will be constant (a non-magnetic wedge will be inserted between the launch bearing and the magnet). When the launch bearing is released, it will be attracted to the magnet, when it strikes the magnet its energy is transferred through the 3 bearings on the other side of the magnet, thus releasing the 3rd bearing in line to travel down the launcher. The time the 3rd ball bearing takes to travel one foot (12 inches) will be determined by using an LED timer. All variables will remain constant except for gravity. The ball bearing will be launched in the classrooms before flying, to act as a control, determining the speed at 1G. It will then be launched multiple times during microgravity (0G) and during hypergravity (2G) to determine if the speed will be affected by gravity. Upon completion of the flights and all testing, the data from each will be compared and conclusions made.

Educators from Ocean Breeze monitor their experiment in parabolic flight.

Peak School & Flagstaff Unified School District: Flagstaff, Arizona
Does G-Force Affect Bubbles?

Kids are fascinated with bubbles whether they are big or small, but do they function the same way in microgravity compared to gravity? This is what our team of schools across five grade levels is trying to figure out.

The question that they are focusing their investigation on is how long does it take for a bubble to pop in gravity compared to microgravity? We want the students to test the effect of gravity, or lack of, on the surface tension of soap bubbles. Our students want to time how long it takes bubbles to pop in gravity and free fall to see there is a relationship between the effects of gravity on surface tension. In gravity the soap film moves to the bottom of the bubble making it thinner at the top, which eventually thins out so much that the bubble pops. Without gravity moving the soap film to the bottom of the bubble, we would like to measure how much longer it stays intact at different levels of gravity. Does gravity have a linear, logarithmic or exponential effect? Or is there no discernable pattern?

We are using Skype technology to bring together our four classrooms in two different states to collaborate together. Students have used the scientific method to create their own bubble solution consisting of water and Dawn liquid dish soap that creates a short lived bubble. Our students timed and observed how long it took various sized bubbles to pop in gravity to compare if there is a relationship between the effects of gravity on the surface tension of bubbles. They video recorded images of the bubbles leaving the device and popping. Students then uploaded the video material to video editing software so that they could review the exact times of bubble formation and collapse to add to their data. Our students hypothesized that bubbles will last longer in microgravity. The team of teachers will conduct the same investigation on the plane, record data, and then share the data with their students to analyze and compose a final report about the effect of gravity, or lack of, on the surface tension of soap bubbles. Our students will then share their findings with their schools, their communities, and other school communities across the country using Skype.

Portland Public Schools: Portland, Oregon
The Cartesian Diver in Space

As space travel becomes more common place, understanding gravity will dictate the lengths of time people stay or live in space and ultimately where people live. The Cartesian Diver in Space experiment will test how a varied gravitational environment (both decreased and increased gravity) affects the density of the 'diver'. Many scientific concepts apply to this experiment. It will create a physical representation of the concepts of pressure, buoyancy, density, gravity, and the compressibility of air and water in 0 gravity, 1 gravity, and 2 gravity.

The Cartesian Diver is based on air pressure and buoyancy. This is a demonstration of "Boyle's Law" which relates pressure and volume. Archimedes principle says the force of gravity pushes down and the force of buoyancy pushes up and that this is what allows an object, such as the diver, to float. The diver remains vertical in the soda bottle due to the small air bubble captured inside it. Liquids are not compressible. If an object is placed in water, for example, the water will be displaced – will move to another area. Gasses are compressible. A gas will expand into a larger space, or compress into a smaller space depending on the pressure exerted upon it. In this experiment, when the bottle is squeezed, and subsequently released, we are seeing the exertion of pressure upon the air bubble. The Cartesian Diver also demonstrates Pascal's Principle as well. Squeezing on the top of the sealed plastic container decreases the volume and therefore increases the air pressure above the water. By Pascal's Principle, the pressure is transmitted to all parts of the container. This increases the pressure inside the diver. The higher pressure decreases the volume of air at the top of the diver, and in so doing, decreases the amount of water displaced by the diver. This increases the buoyant force on it enough to cause it to sink. The diver sinks because the volume of the air decreases.

The main problem the P.P.S. High Flyers will be trying to answer is "What effect does microgravity have upon a Cartesian Diver? When the sides of the 1-L bottle are squeezed, will the Cartesian Diver sink or float in microgravity? Other questions we will attempt to answer are: What, if anything, will happen to the control bottle in microgravity? Why does the diver sink? Will the diver 'dive' at a similar or different rate as compared to earth's gravity? What happens to the volume of the bubble in the diver? Why would this volume change make the diver behave the way it did? What kind of changes in pressure is a diver subject to?

The PPS High Flyers hypothesize that the diver will sink and rise at a slower rate in 0g and move at a faster rate in 2g. We believe that the air bubble will compress more quickly in 2g than on Earth and the air bubble will compress less quickly in 0g because gravity would seem to affect Boyle's law which relates pressure and volume This prediction is based on how the two forces of gravity and air pressure are acting on the Cartesian Diver. Gravity is pulling the diver down and buoyancy is pushing it up.

Warren Tech: Lakewood, Colorado
I'll Take Mine Sunny Side Up, Please: The Preparation and Cooking of Eggs in 0G

This experiment is being flown as part of the Teaching From Space program. It was designed by the teachers from Warren Tech's Culinary Arts program, STEM program, Automotive Technology program, and Construction Technology program. The reason for doing the project is to provide information relevant to the procedure and design of an experiment that will determine the feasibility of cooking fresh eggs in space. The experiment will test procedures for cracking open eggs and removing the contents without disrupting the yolk of the egg. The teachers will observe the behavior of the egg contents in zero gravity; determine the adhesive qualities of the egg contents and the egg shell in zero gravity; and experiment with different techniques to crack open an egg in zero gravity.

Educators from Warren Tech work with their experiment in parabolic flight.

Astronaut food has long been a topic of discussion – for example, variety, preparation, longevity (shelf life), mode of storage, and palatability are all factors influencing decisions made about what astronauts end up eating. Our experiment investigates one small arena of astronaut food, that is, the preparation and cooking of a sunny-side-up egg. On Earth, gravity is a crucial factor in cracking open and egg, removing the contents without disrupting the yolk, and ultimately cooking the egg on a heated surface. How exactly does one remove a gelatinous mass from a rigid container while minimizing contamination? How does one adhere a gelatinous mass to a heated surface and then be able to remove that mass once it's cooked?

Department of Energy/Princeton Plasma Physics Laboratory – By State

** First Time Participant (institution)*

Team 1:
Surface Tension of Bubbles Experiment

This experiment originated in team member Susan Franko's fourth grade classroom with the question, "What happens to bubbles in zero-gravity environments?" The resulting experiment has been designed to answer that question. Liquids possess a property known as surface tension. This property allows liquids to resist an external force, to a certain extent, when it is presented.
An example of this property is the fact that certain lightweight solid objects can be held up by the surface of a liquid regardless of their density in comparison to the supporting liquid. Surface tension in liquids is created because of the cohesive forces present in the liquid molecules themselves. Most molecules in a liquid are pulled by forces from neighboring molecules in all directions, however molecules at the edges of a liquid sample are. The molecules at the edges are pulled inward toward the center of the sample and tend to force the liquid sample into a spherical shape. Bubbles are an example of this property, and are therefore an appropriate medium to use for surface tension experimentation. Bubbles are easy to see and count, and inexpensive to buy or make, allowing this experiment to be easily replicated in a classroom setting. In addition, the science of bubbles can be studied while examining of the properties of solids, liquids and gases, a recurring standard in the NJCCCS from grades K-12.

Oscillator in Microgravity Experiment
A force on an object that tends to return it to its equilibrium position is known as a 'restoring force.' Objects acted on by restoring forces end up oscillating around their equilibrium positions. In introductory physics classes, two situations in which restoring forces act are often studied: a mass on a spring and on a pendulum. This experiment will investigate both.

For a mass on a spring: the force exerted on the mass by a spring is, ideally, proportional to how far away from equilibrium the spring has been stretched or compressed. (This proportion is known as Hooke's Law.) When a spring that obeys Hooke's Law drives a mass connected to it, the resulting motion of the mass is an oscillation about its equilibrium position. A motion probe measuring the position of the mass in time would show a sine function for the graph of the mass' motion.

Team photo on the plane before flight.

A pendulum acts in a similar way, except the driving force is the force of gravity rather than a Hooke's Law spring. Since this equation does not contain g, the mass on a spring should maintain the same frequency throughout the flight. However, when the mass on the spring hangs vertically, rather than slides horizontally, the equilibrium location will shift downward by a distance equal to mg/k where k is the 'spring constant' in Hooke's Law. So we should observe that equilibrium location rise and fall with g during the flight.

The equation for the frequency of oscillations for a pendulum does contain g, therefore, we should see the pendulum's frequency decrease as g decreases and increase as g increases. We should not, however, see its equilibrium location shift.

Team 2:
Crystallization in Zero G

This experiment will study the crystallization rate and the properties of the resulting crystal in varied gravity environments, microgravity, lunar gravity, Mars gravity, Earth's gravity and 2-g. The model chosen for the crystallization experiment is sodium acetate ($NaC_2H_3O_2$) from a supersaturated solution around stationary seed crystals of various sizes. Crystallization rates and the resulting crystal structures of sodium acetate are well known in Earth's gravity. Crystallization process is exothermal and so depends on heat transfer mechanisms. Microgravity environment affects convective flows and therefore is expected to affect crystallization processes. Simulation of other gravitational environments is relevant to the understanding of rock formation on other terrestrial planets. It is also expected that the size of the seed crystal is going to affect the crystallization process since these crystals present different surface areas to the squirted liquid globule. The changes in the crystallization process will be determined from a video recording as well as additional analysis of the products after the flight.

A saturated $NaC_2H_3O_2$ solution will be prepared prior to flight and loaded into syringes (heat resistant plastic or metal tubes fitted with plungers are sufficient). These syringes will be kept in a hot water bath until needed. The water will be preheated and kept hot using insulation and a small electrical heater or just insulation. Seed crystals of various sizes will be set up in the middle of transparent acrylic containers. The containers with the seed crystals will be fixed in a linear or circular rack. The containers with the crystals will not move before or after the experiment. At the time of the approach to zero-g, a syringe will be inserted into the container and the solution squirted into the acrylic container (with the seed crystal). The emergent solution will cool and become supersaturated. Crystallization will occur upon contact with the seed crystal and the walls and end in 20 – 30 seconds (from 1-g). This procedure will be repeated with four syringe-container combinations with various size seed crystals. An identical set of four solution-seed combinations will be used for 0.37-g and 0.16-g if these are available. If these are not available, and additional set of measurements will be conducted in zero-g. The crystallization process will be video recorded. All additional measurements will be conducted upon return to NJ.

Team 3:
Collisions in Microgravity (Splash, Bounce, Plop)

The purpose of this experiment is to study the splash dynamics when spheres with hydrophilic and hydrophobic coatings are launched downwards at varying speeds into a hermetically sealed tank of water in microgravity and hypergravity.
The miscibility of the spheres' coatings with water, along with their velocity, should cause the spheres to bounce off the surface of the water, merge with the water, or create a hollow cavity and subsequent splash. It is suggested that the collision and resulting splash is related to gravity and that analysis of splash dynamics in microgravity and hypergravity may yield surprising results. The spheres will be launched using a solenoid actuator to vary the speed. The resulting collisions will be recorded using a high-speed camera and then synchronized with accelerometer data for analysis on the ground.

Team 4:
The Equilibrium of Solids and Liquids in Microgravity and Hypergravity

This project will consist of several small experiments that seek to explore the equilibrium condition of solid and liquid systems under the influence of microgravity and hypergravity. By studying both regimes, our team seeks to take advantage of all phases of the parabolic flight as well as presenting a broad range of experimental conditions that can be explored in the classroom.

Mechanics experiments:
Two mechanics experiments are considered. The first is a static equilibrium. Here, a series of ring-shaped permanent magnets will be arranged in a floating configuration. The magnets will be placed in a sealed plastic tube. As the flight transitions between hypergravity and reduced gravity phases, we anticipate observing a change in the height of the magnets. A calibrated scale attached to the tube will allow for measurement of the heights of the different magnets. The change in spacing will be recorded by video camera.

The second mechanics experiment is a dynamic equilibrium. Here, a small parachute will be released in a drop tube and its rate of fall will be measured by video camera. The motion of the parachute during the microgravity and hypergravity portions of the flight will be compared to a standard classroom experiment using a similar parachute with the drop tube in a classroom experiment.

Fluid experiments:
The fluid experiments seek to explore the role of gravity in determining the characteristics of fluid systems. Each of these experiments will be a closed system that will be observed using the same video cameras used for the mechanics experiment. Three experiments are considered.
a) Bubble formation and growth – In this experiment, an antacid tablet will be released into a cylinder of water. Under 1 g conditions, it is known that the bubbles formed in the interaction with the water rise due to their lower density than the surrounding liquid medium. However, under microgravity conditions, both the dynamics of the formation, the separation of the bubble from the generating surface, and the motion of the bubble are all likely to be impacted. Using high speed imaging, the experiment will compare the bubble formation process between the laboratory and a ground experiment
b) Density columns – Density columns are commonly used teaching tool used to illustrate the concept that different objects can have substantially different material properties. However, the separation of fluids of different densities is aided by the action of gravity. If gravity is reduced or enhanced, this will change the rate at which the fluids separate. Additionally, some of the dynamics of the separation will likely be altered during the microgravity and hypergravity phases of the flight.
c) Pump experiment – This experiment is a combination of a fluids experiment and a biological experiment. The key goal will be to investigate if microgravity and hypergravity have an impact on fluid pressure (e.g., as in an astronaut). Here, the goal would be to use a small pump to circulate water in a closed loop. The top of the system is the "head" and the bottom of the system would be the "feet". Digital pressure gauges would read out the pressure in the system during the flight.

Educators present their experiment to the TRR committee.

Team 5:
Analysis of Burn Patterns, Efficiency, and Exhaust for Internal Combustion in Microgravity

Based on prior research, we know that fuel droplets will change shape (become more spherical) in 0g which slows the burn rate. To test the effects of gravity on combustion, we can adjust timing and air fuel mixture. We will monitor exhaust gas to see the effect, especially on NOx. What will happen at 2g? Can we assume the corollary? Will 2g cause an increased burn rate due to elongation of the fuel droplet? We will adjust timing and air fuel ratios to maximize the power / efficiency of that cycle while minimizing the exhaust. Input variables include air fuel ratio, combustion timing, air temperature. Output variables include power output, fuel use per cycle, instantaneous fuel consumption, exhaust gas, combustion chamber temperature, and visual burn pattern and an infrared visual burn pattern.

We will run an internal combustion engine using propane as the fuel. The engine is a single cylinder, four-stroke internal combustion engine that has the engine block made out of plexiglass. This allows the user to see inside the combustion chamber while the engine is running.

As we run the engine, we will vary air/fuel mixture and ignition timing. We will use a 5-gas analyzer to monitor and collect exhaust data (NOx, HC, CO, CO2, O2) and the temperature sensor to monitor cylinder head temperature. The gas analyzer is a self-contained unit with data storage. The temperature sensor and mass flow meter still have to be chosen which will determine the data collection method. We will measure fuel consumption instantly, using a flow meter. (We hope to have the version of this engine that has a built-in dynamometer which will give us instantaneous power – this will allow us to calculate instantaneous fuel efficiency.)

In addition to the data captured, we will also look at the burn pattern under varying gravity using an infrared and high speed camera. These images will provide visual burn patterns and infrared patterns.

Team 6:
Investigation of Complex Fluids in Microgravity

This study of complex fluids in microgravity seeks to analyze the multi-phase phenomena often masked by the effects of gravity. The complex fluids will be contained in transparent chambers that will allow for three dimensional visual observations. A video camera will be used to observe and record the behavior of various characteristic complex fluids. In addition, sound wave amplifiers will be used to apply controlled acoustic pressure for the characterization of effects of stresses and strains of the complex fluids while in the microgravity environment. Aside from the scientific work, this project's scientific data and results will be used to develop educational curricula on the science of Newtonian and non-Newtonian (complex) fluids that will be subsequently used in various K-12 curricula.

In this experiment a solution of a complex fluid such as "oobleck" will be injected into two resonance tubes, an experimental and control. The tubes allow us to add a stress/strain from an acoustical speaker on the experimental and the control does not apply any acoustical pressure. That will allow us to study the behavior of this fluid under the following conditions: changes of gravity, sound amplitude, and resonance length and frequency. The experiment will be attempted on earth then repeated onboard the aircraft during both microgravity and the varying gravitational portions of the flight. The hypothesis is that the action of the fluids will change in the varying gravitational environment. During the flight, all experiments will be videotaped for further analysis.

Appendixes

Top, left: Students taking data during the microgravity portion of a parabola.
Middle, left: Student monitor experiment during flight.
Bottom, left: Students working with their free float CubeSat during their flight.
Top, right: Students taking a team photo on the aircraft prior to flight.
Middle, right: Educator taking data from their student's experiment.
Bottom, right: Educator from Bob Jones High School taking data from their students' experience.

Appendix 1 – Proposals at a Glance

Undergraduate Student Program
Selected Engineering Proposals

Institution	Proposal Title	Page
California Institute of Technology	Self-Deployable Space Structures	6
California Polytechnic University	Adaptive Control Experiment (ACE)	7
Dartmouth College	Porous Media Condensing Heat Exchanger for Space Vehicles	7
The George Washington University	Gravity's Effect on the Plateau-Rayleigh Instability	7
Lehigh University	Zero G 'Fly-te' Trajectories	8
Oklahoma State University	Microgravity Deployment of Inflatable Gravity Simulator	8
Purdue University	Scaling Diaphragm Tanks in Low Gravity	8
State University of New York at Buffalo	Line of Sight Relative Attitude Determination	9
University of Florida	Attitude Control Verification Using Miniature CMGs	9
University of Washington	Reduced-Gravity Fluid Transfer Experiment	10
Utah State University	FUNBOE 2.0 (Follow-Up Nucleate Boiling On-flight Experiment)	10
West Virginia University	Electromagnetically Enhanced Fluidized Beds in Microgravity	10

Selected Physical Science Proposals

Institution	Proposal Title	Page
Yale University	Solidification of Fluids and the Formation of Mushy Layers	11

Selected Life Science (Including Biology) Proposal

Institution	Proposal Title	Page
Boise State University	Gravitational Modulation of Calcium Signaling in Bone	6

SEED Program
Selected Proposals

Institution	Proposal Title	Page
California State Polytechnic University, Pomona	AE-COX: Atmospheric Entry with Control in One Axis	12
Carthage College	Non-Invasive Fluid Volume Measurement	12
Northwest Nazarene University	Hydrophobic Surfaces in Micro Gravity	13
Portland State University	Heating/Lighting in Microgravity	13
University of Kentucky	Bubble Free Syringe	13
University of Nebraska at Lincoln	Microgravity Propellant Management Device Investigation	14
University of Texas at El Paso	Evaluation of Exothermic Welding in Reduced Gravity	15
University of Wisconsin at Madison	Fuel Gauging in Microgravity using ECVT	15
Washington University in St. Louis	Measuring Localized CO2 in Microgravity	16

MSI/CC Program
Selected Proposals

Institution	**Proposal Title**	**Page**
Citrus College	The Impact of Viscosity on the Ability of Capillary-Driven Liquids to Spin an Axial Blade under Microgravity	19
Community College of Aurora	Examining the Effects of Gravity on the Human Cardiovascular System and the Effectiveness of Countermeasures	19
Florida Agricultural & Mechanical University	Pseudo-Gravity Application for Autonomous Mobile Robot in a Microgravity Environment	20
Fullerton College	Ferrofluid Energy Production in 1-G and Microgravity Environments	20
Ivy Tech Community College of Indiana	Liquid Photopolymer 3D Prototyping in Microgravity	20
Lake Tahoe Community College	Structural Integrity and Mathematical Modeling of Singular Soap Bubbles in Microgravity and Hypergravity	21
Los Medanos College	The Precision and Accuracy of an Electromagnetic Launching System	21
Palm Beach State College	Effects of Artificial Gravity on Fluid in a Reduced Gravity Environment	21
State College of Florida, Manatee-Sarasota	A Study of Magnetic Forces Between Dipoles During Microgravity Flights	22
Tacoma Community College	Investigation of NAFION Membrane Wetting in Microgravity	22
Tuskegee University	The Formation, Development and Interaction of Ring Vortices in Reduced Gravity	22
University of Puerto Rico at Rio Piedras	Microgravity Effect on Molecular Diffusion in Nanoporous Materials	22
University of Texas at El Paso	The Effect of Gravity on the Production of Structural Materials from Lunar Regolith	23

Grant Us Space Program
Selected Proposals

Institution	**Proposal Title**	**Page**
California State University, Fresno	Formation of Calcium Oxalate in a Microgravity Environment	24
Drexel University	Characterizing the Performance of the CubeSat Deployable Boom in Microgravity	24
Drury University	Hamiltonian Dynamics of a Two Degree of Freedom Robotic Arm with Viscoelastic Muscles in Microgravity	25
Lamar University	Collection of Water Droplets and Mist by Electrostatic Fields	25
Missouri University of Science and Technology	Testing of a Refrigerant-Based Cold Gas Propulsion System in a Reduced Gravity Environment	26
Northwestern University	Cathode Surface Geometry as a Factor in Electrolysis in Microgravity	26
University of Arizona	Analysis of Gravitational Effects on Liquid Lenses (ANGEL)	27
University of Arizona	Organic Compound Synthesis in Extraterrestrial Conditions	27
University of California, San Diego and Grossmont College	Intracranial Pressure in Microgravity	27
University of Colorado at Boulder	ALL-STAR Microgravity Structural Deployment and Attitude Control Test	28
University of Florida	Chilldown Process of Cryogenic Transport Lines in Reduced Gravity	28
University of Illinois at Urbana-Champaign	Space Parasites: Exploring Nematode Behavior in Reduced Gravity Environments	28
University of Michigan	Autonomous Boom CubeSat Deployment Experiment: ABCDE	29
University of Pennsylvania, Rose-Hulman Institute of Technology and Seattle Pacific University	Granular Impact Cratering in Microgravity and Hypergravity	30

Teaching From Space Program Selected Proposals

Institution	Proposal Title	Page
All Saints' Episcopal School	Boiling Without Pressure in Microgravity	31
Bergen County Technical Schools	Helium Balloon Buoyancy in Microgravity	32
Bob Jones High School	3D Printing in Microgravity	32
Boston University Academy	Overclocking a Pendulum	33
Central Florida Aerospace Academy of Kathleen High School	The Ups & Downs with Colloids	33
Clear Lake Intermediate School	Acceleration in Reduced Gravity	33
Elgin Public Schools	Stimulant/Depressant Effects on Daphnia	34
Glenbrook North High School	Magnetic Fields	34
Highland Park Middle School	Mentos and Diet Coke	34
Lake Oswego Junior High and High School	Chillin' at 0g's	35
LiftOff Alumni	Systematic Planet: A Cretion Experiment (SPACE)	35
Marble Falls Independent School District	Maintaining Proper DO Level	36
The Master's Academy	Chemical Reactions in a Reduced Gravitational Field	36
Miami Dade County Public Schools	Worms in Space	36
Midway Independent School District	The Amazing, Floating, Flying Air Pellets	37
Mountview Road School	Magnets in Space	37
Nederland Independent School District	Separating Liquids in Reduced Gravity	37
Ocean Breeze and Surfside Elementary	Gravity and Magnets: Forces Explored	38
Peak School & Flagstaff Unified School	Does G-Force Affect Bubbles?	38
Portland Public Schools	The Cartesian Diver in Space	39
Warren Tech	I'll Take Mine Sunny Side Up, Please: The Preparation of Eggs in 0G	39

DOE/PPPL Program Selected Proposals

Team	Proposal Title	Page
Team 1	Surface Tension of Bubbles Experiment	41
Team 2	Crystallization in Zero G	42
Team 3	Collisions in Microgravity (Splash, Bounce, Plop)	42
Team 4	The Equilibrium of Solids and Liquids in Microgravity and Hypergravity	42
Team 5	Analysis of Burn Patterns, Efficiency, and Exhaust for Internal Combustion in Microgravity	43
Team 6	Investigation of Complex Fluids in Microgravity	44

Appendix 2 – Demographic Data

Top, left: Student enjoying the microgravity experience.

Middle, left: University of Texas at El Paso explain their experiment to the TRR committee.

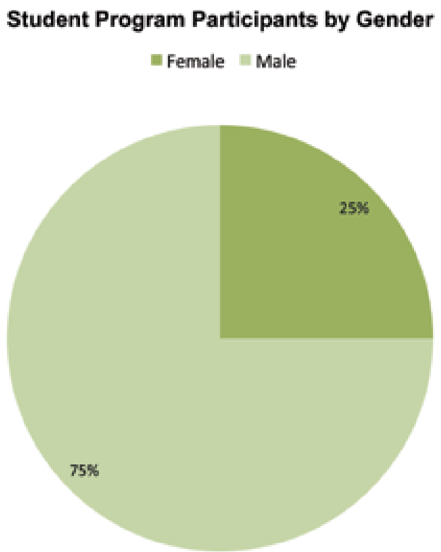
Bottom, left: Students make last minute adjustments to experiment before the parabolas begin.

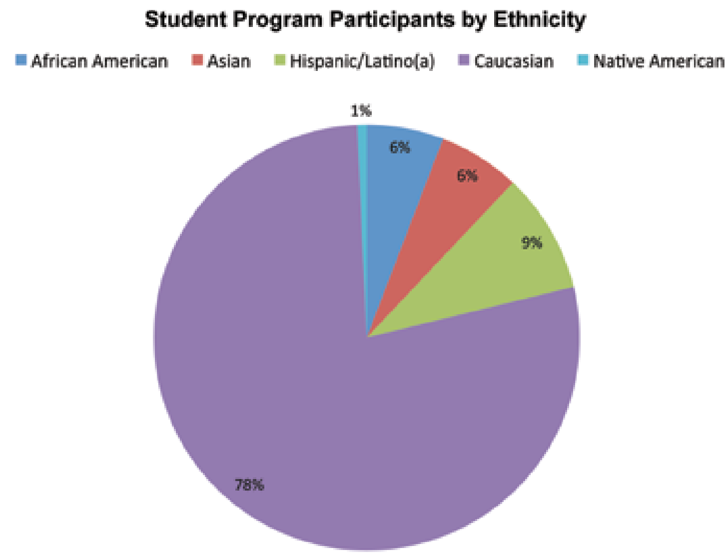
Top, right: Flight team floating with their experiment in microgravity.

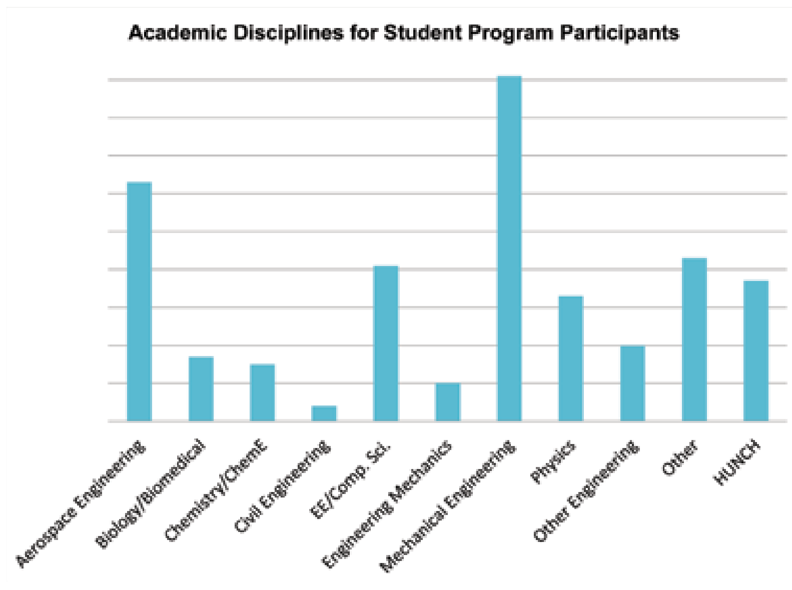
Middle, right: Educator and NASA Mentor, Sarah Ruiz enjoying the microgravity environment.

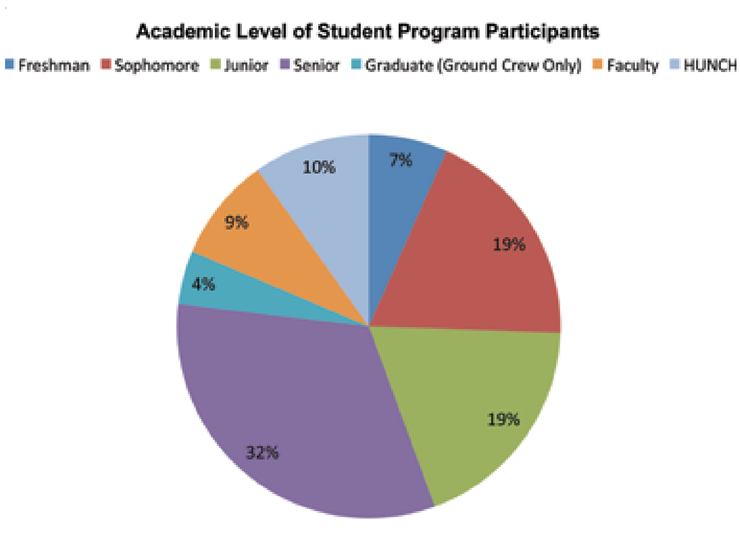
Bottom, right: Flight team watching their hardware float in microgravity.

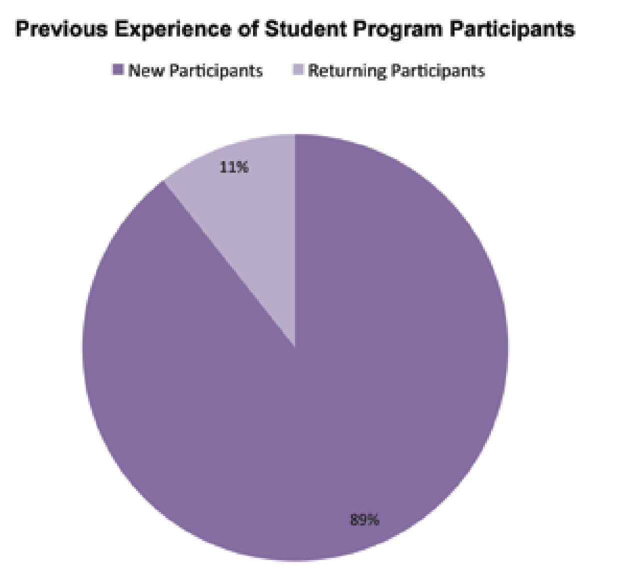
Combined Undergraduate Students Demographic Information (UGrad, SEED, MSI/CC & Grant Us Space)



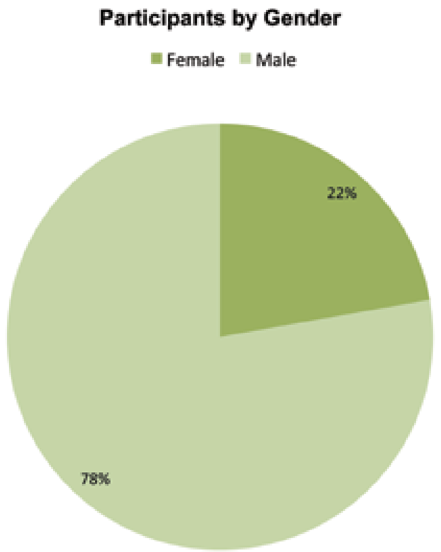


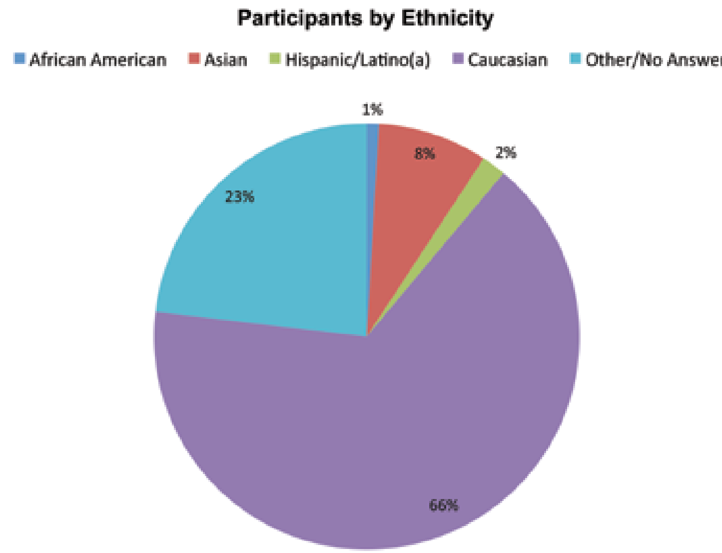


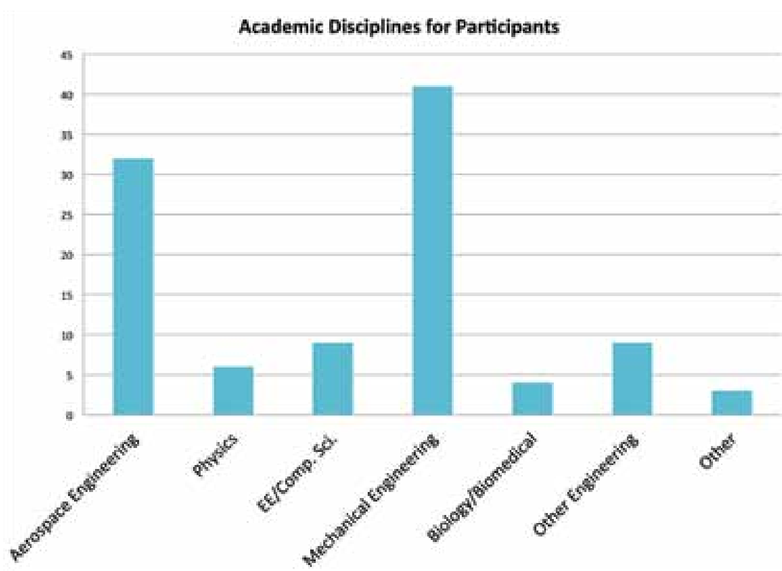


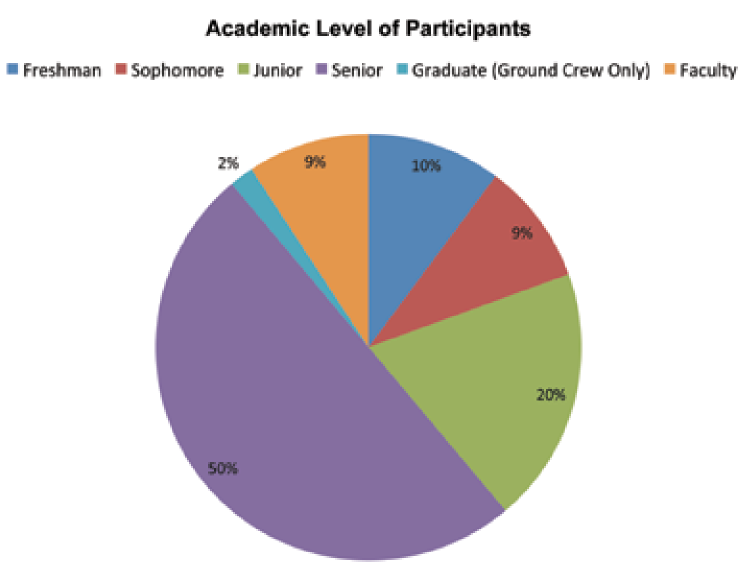


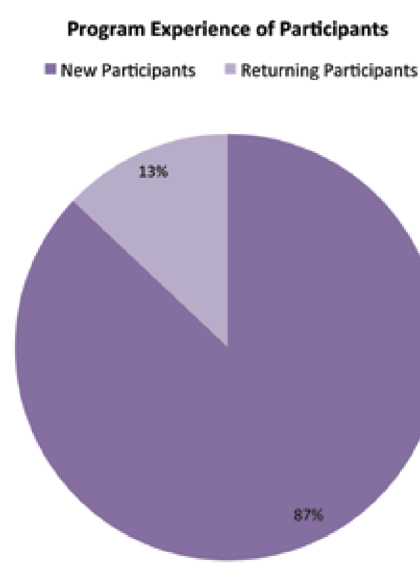
Undergraduate Student Program Demographic Information



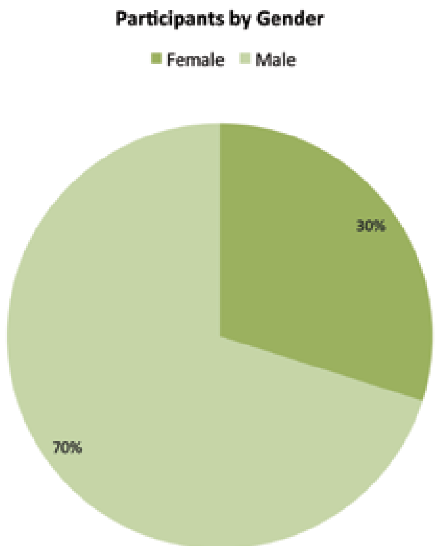


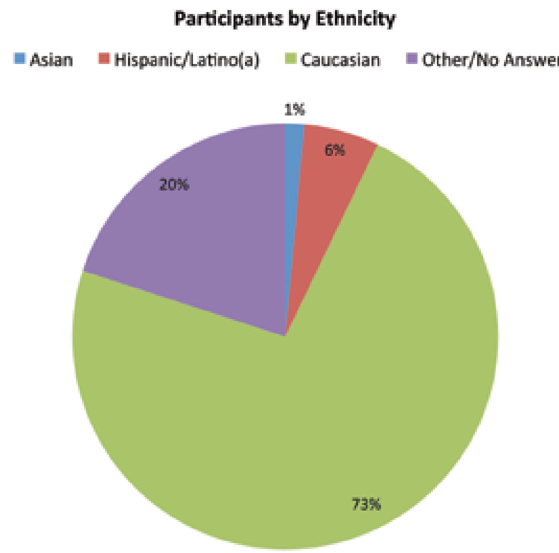


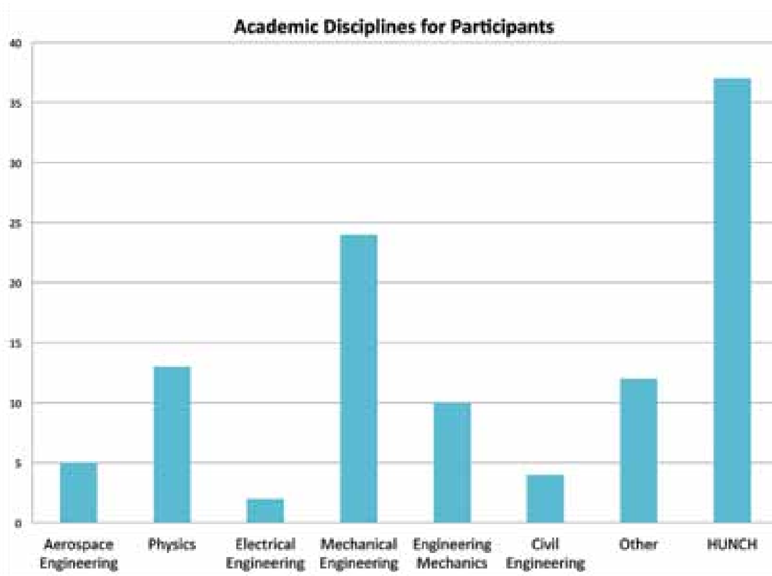


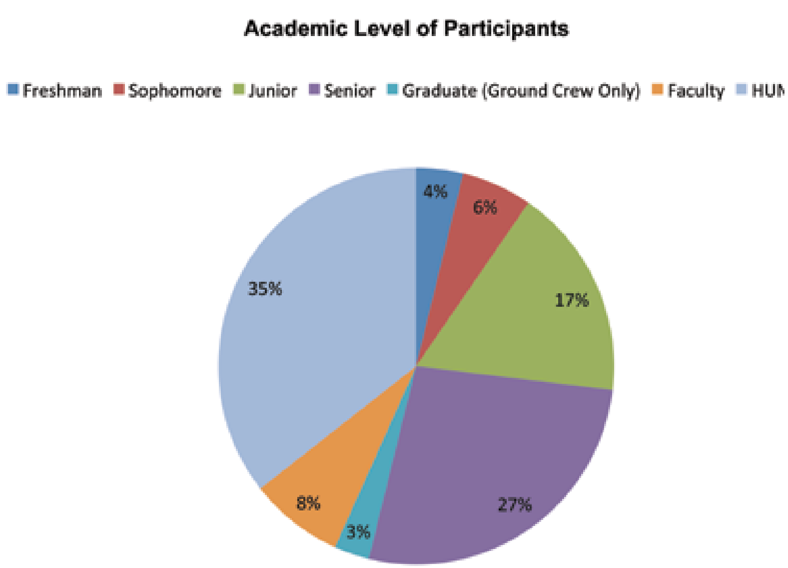


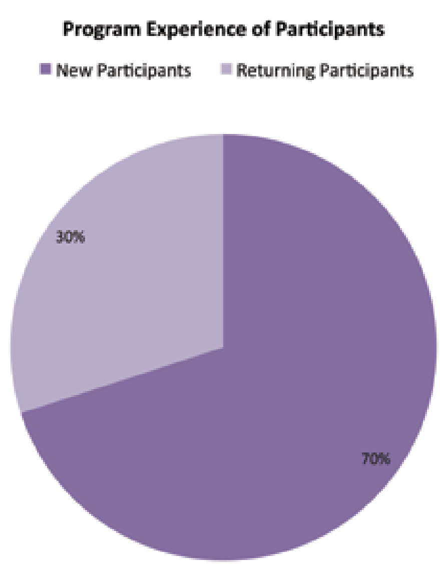
Systems Engineering Educational Discovery (SEED) and HUNCH Demographic Information



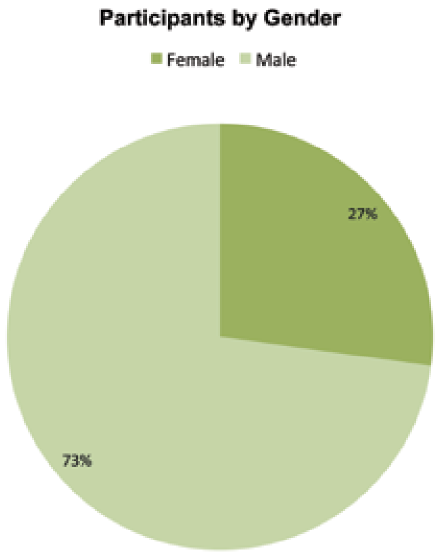


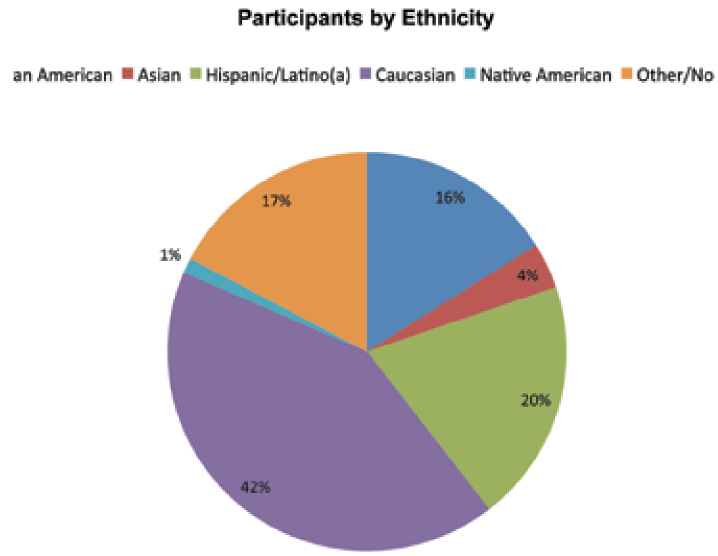


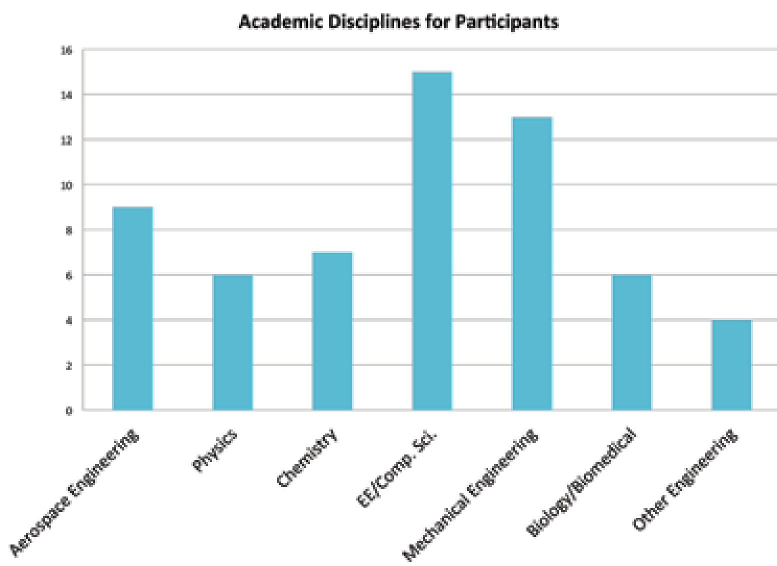


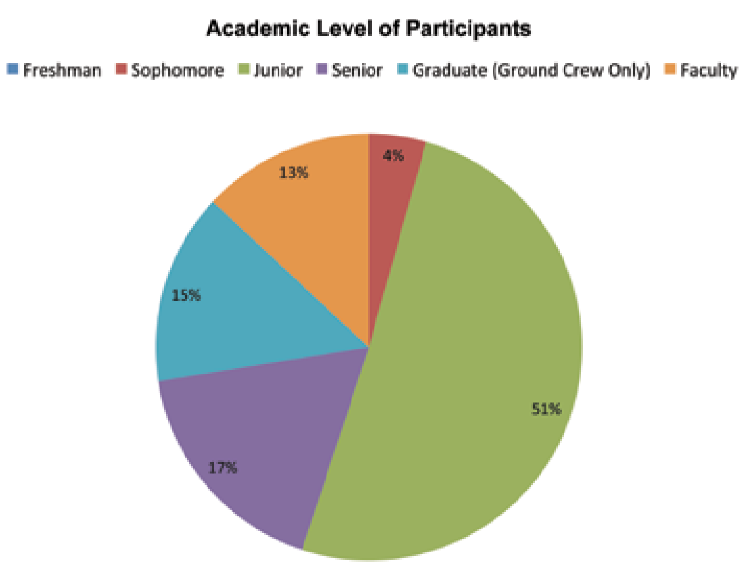


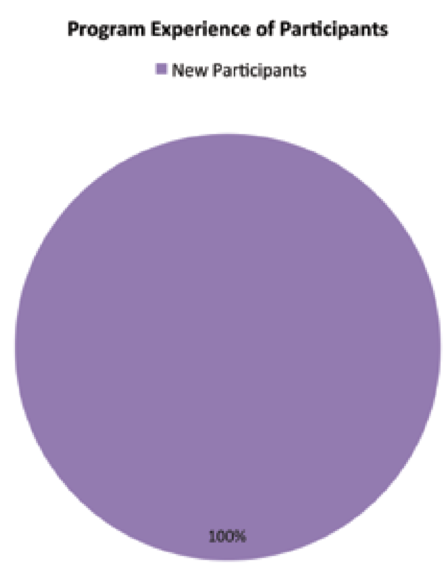
Minority-Serving Institutions and Community College (MSI/CC) Demographic Information



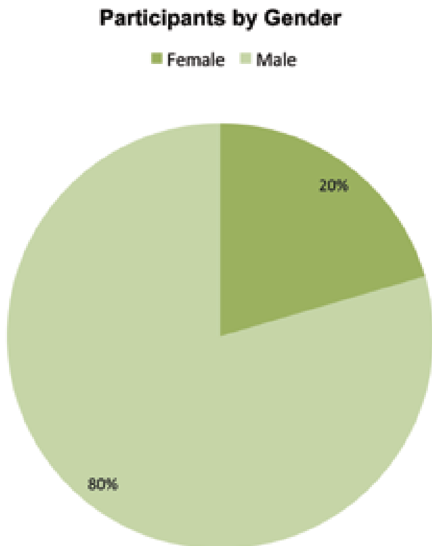


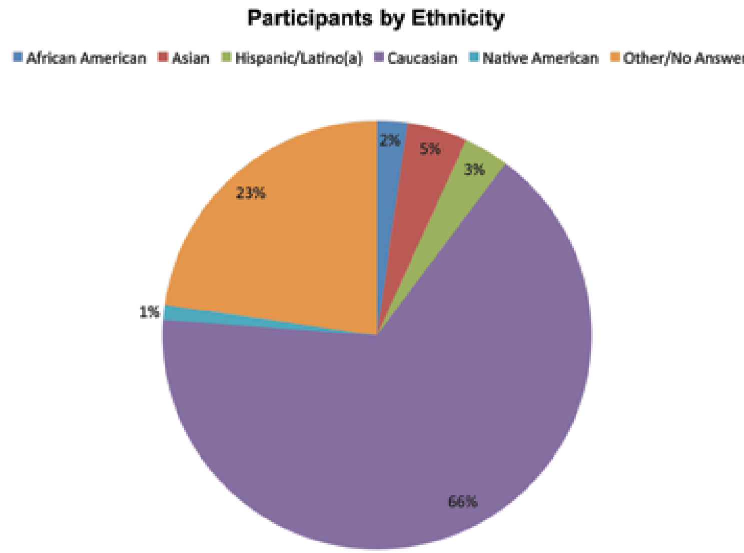


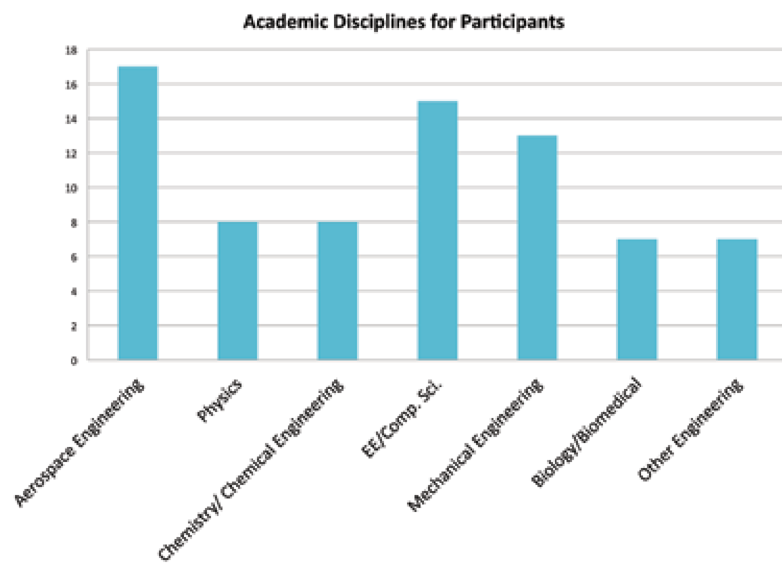


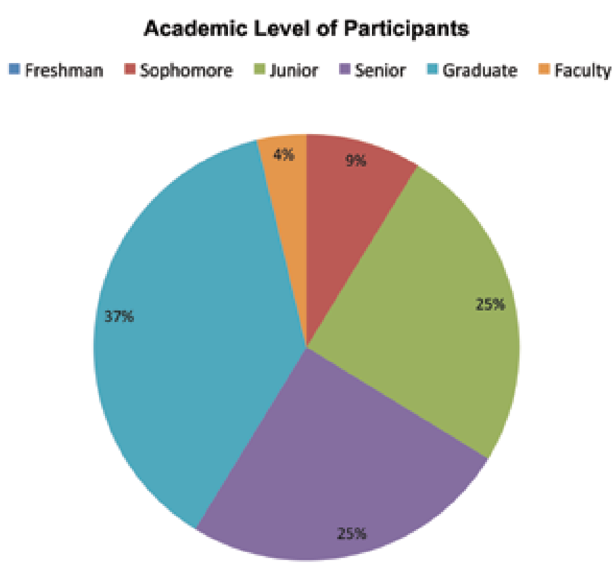


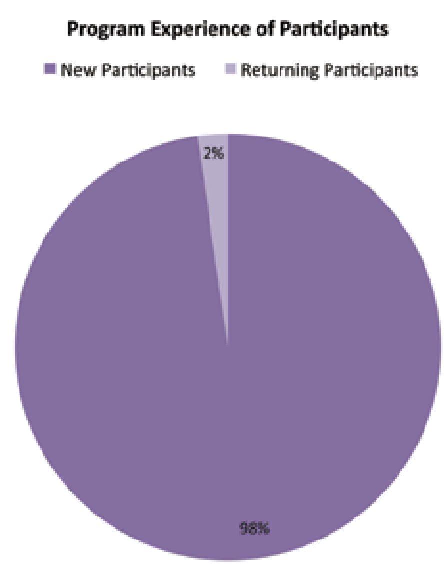
Grant Us Space Demographic Information



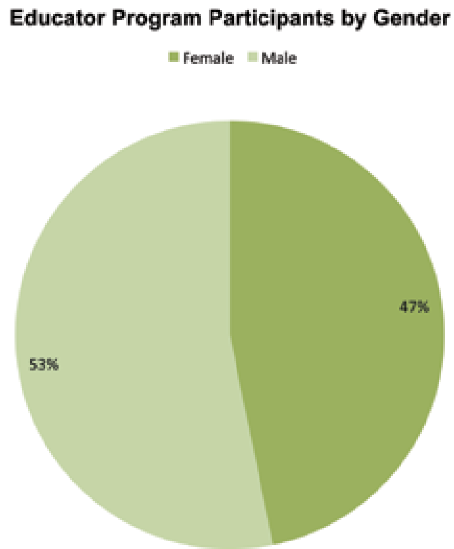


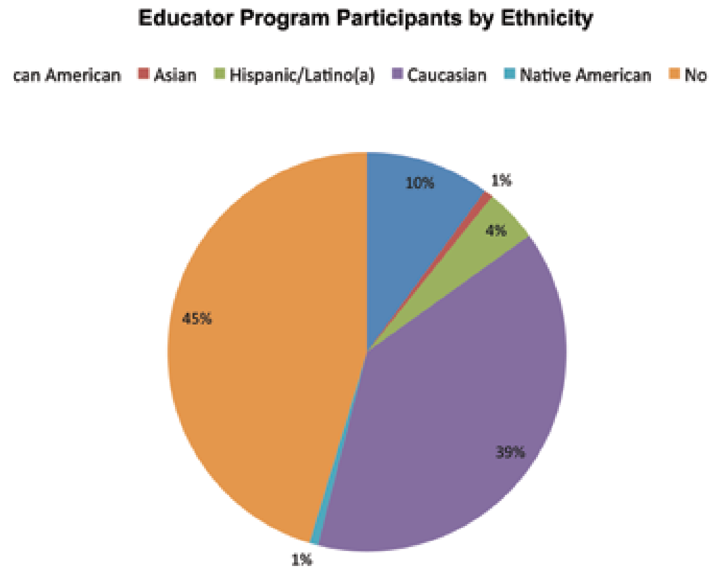


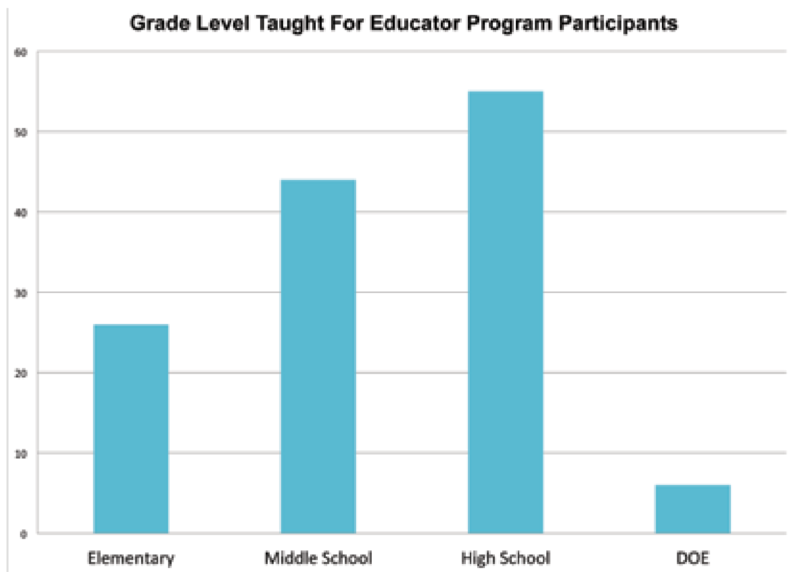


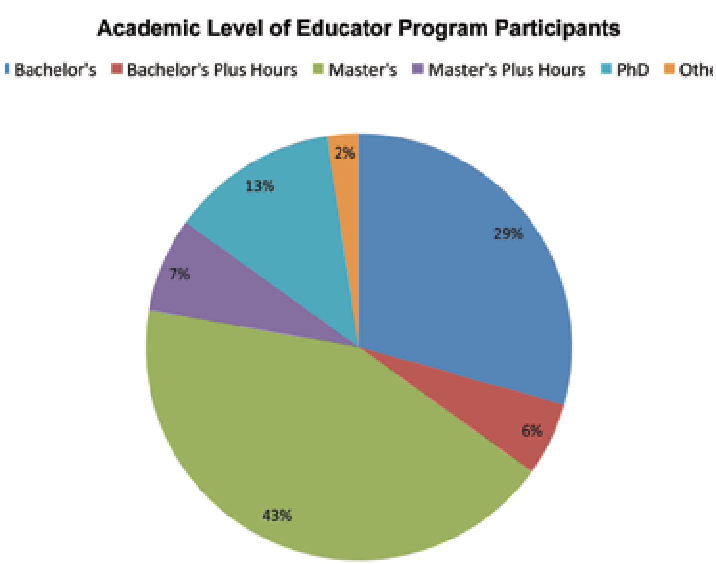


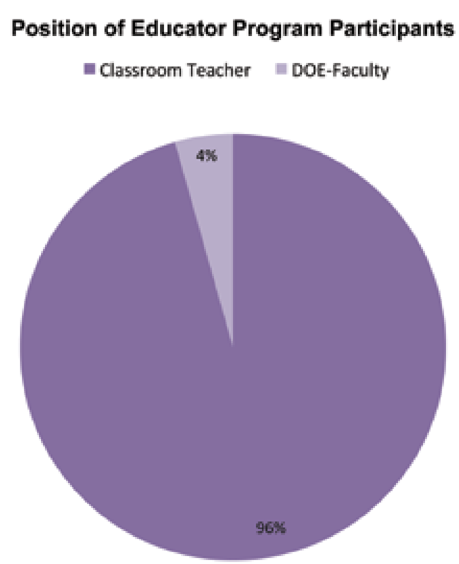
Combined Educator Demographic Information (TFS & DOE)



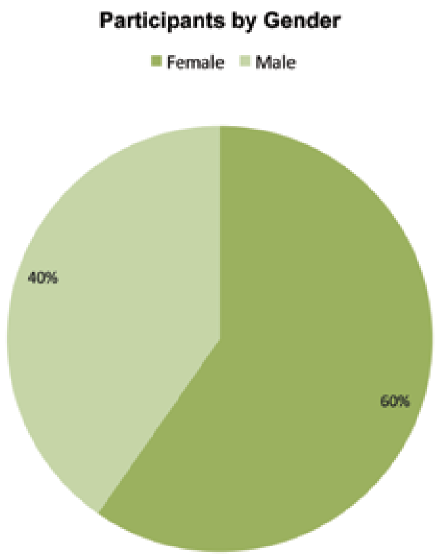


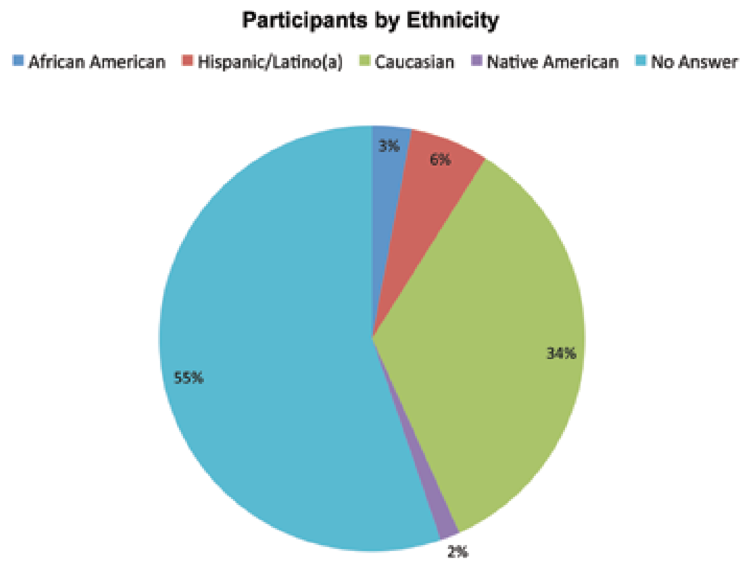


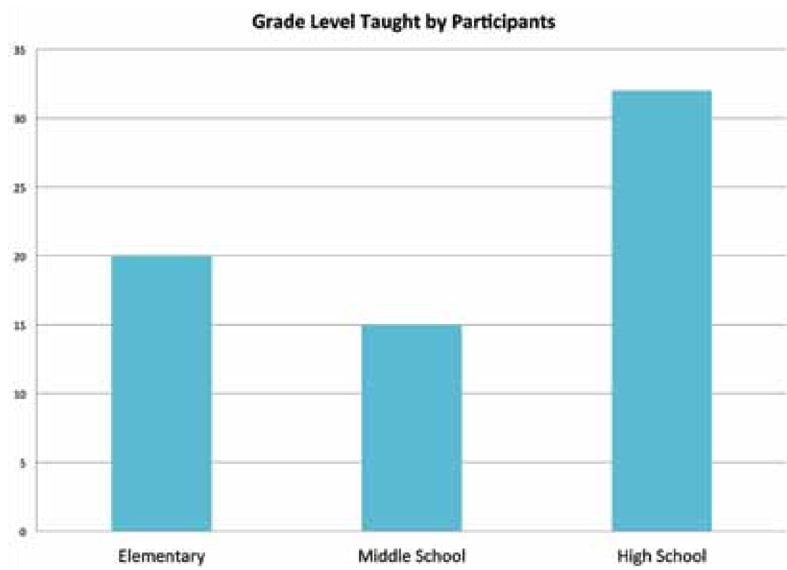


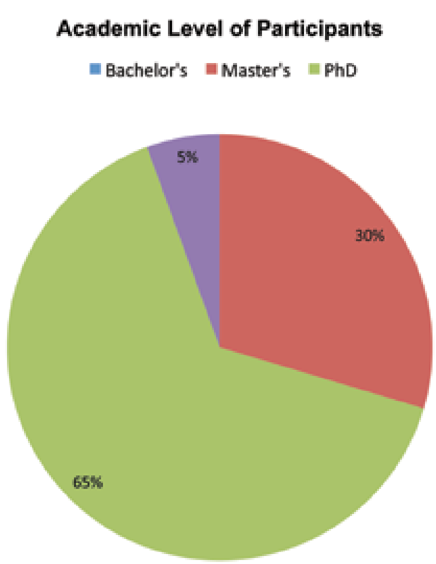


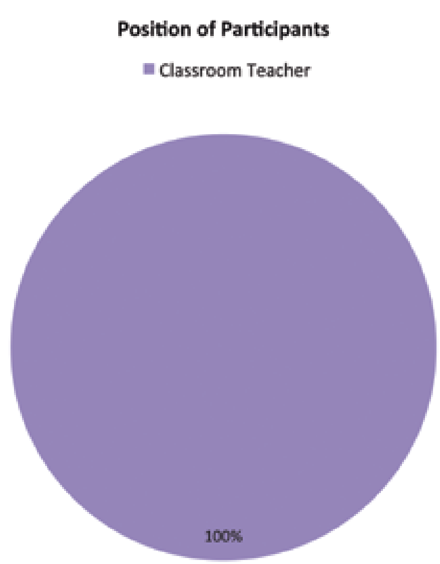
Teaching From Space (TFS) Flight Week Demographic Information



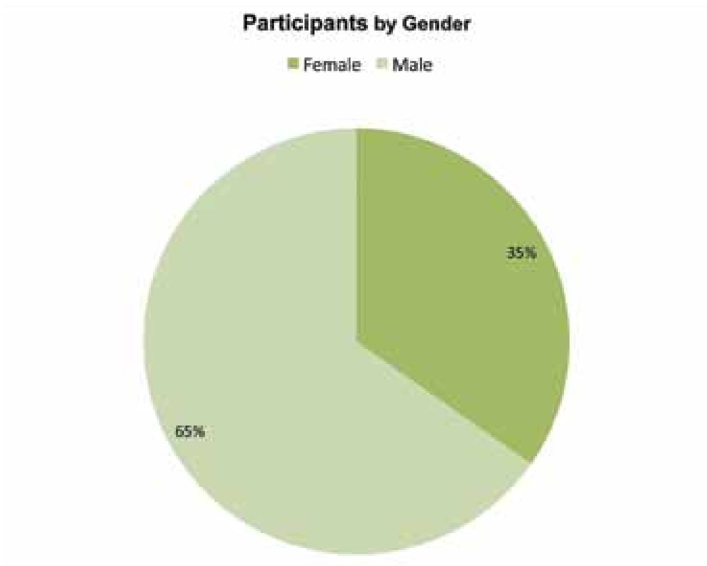


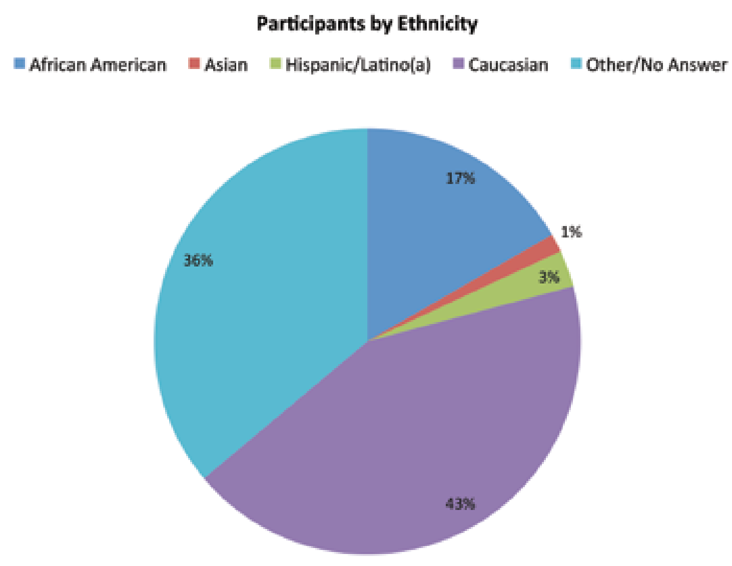


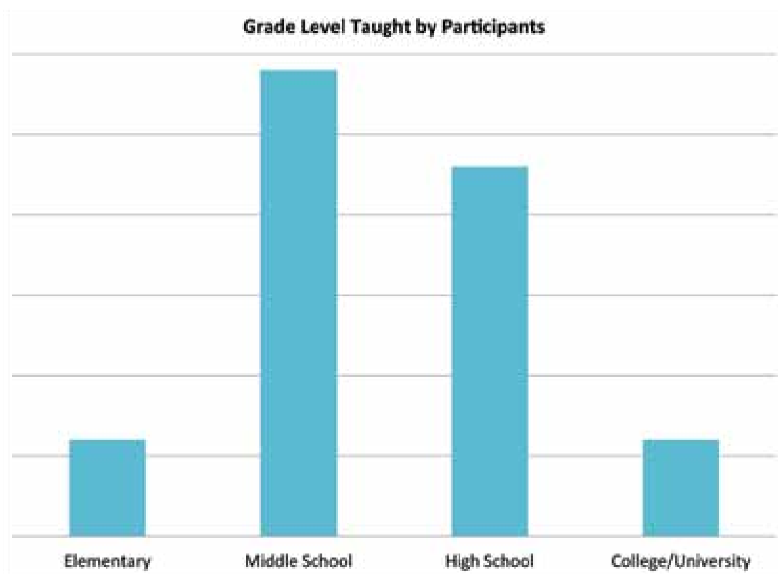


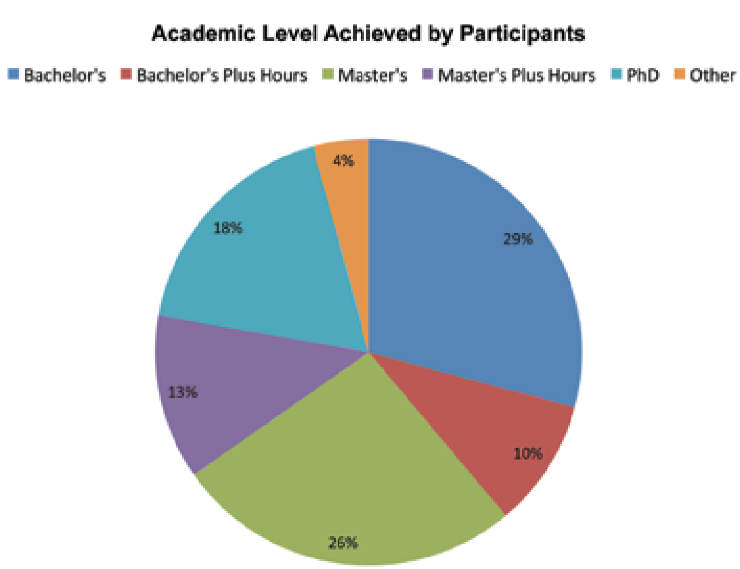


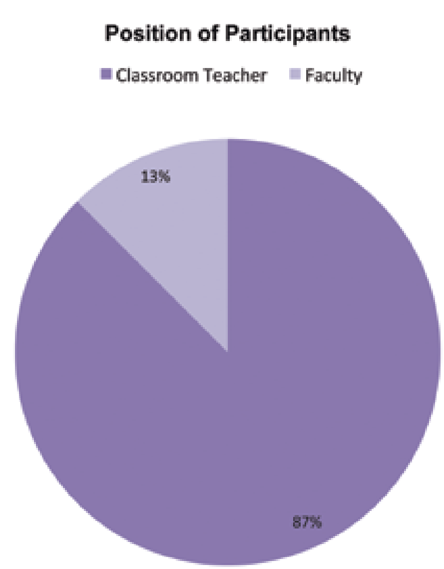
Department of Energy/Princeton Plasma Physics Laboratory and TFS Flight Week Demographic Information











Appendix 3 – Participant Comments

Program evaluations were collected post-flight. Educators, students, and faculty overwhelmingly praised the program for providing a rare real world hands-on engineering experience for K-12 and university students. A few of the educator and student responses follow.

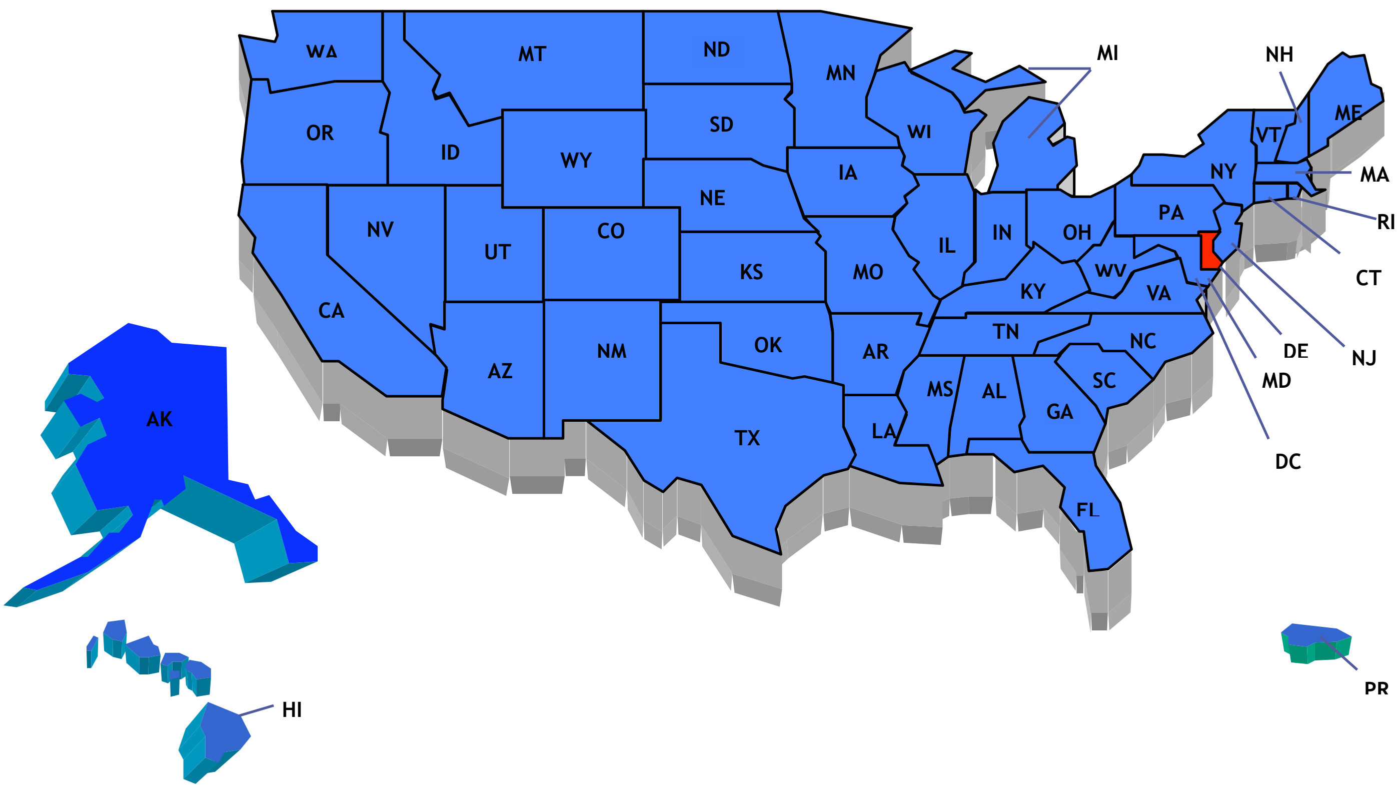
- “The program is definitely the kind of thing NASA needs more of because in reality all these kids who dream of being astronauts probably won’t be selected. I read a statistic that the chances of being an astronaut were slimmer than being a professional athlete who gets struck by lightning! So really this is a program that lets kids get as close as they can to their dreams and feel like “Hey I did something awesome and it involved science and experimentation and engineering.” I really think this program does a great job of doing that and is worth every second of the work - even without the flight. You learn how to actually put together real research and prepare a real experiment to fly. That kind of experience is invaluable and can only serve as a benefit in my future endeavors.”
- “The experience was enriching, fantastic and inspiring. The staff took care of all of our needs. They are a very professional group of leaders and great hosts. NASA should keep the focus on expanding its base to reach even further, more and more people at all levels of schools and from all backgrounds. This type of experience makes students correlate the books and the actual doing, and will definitely motivate students to look at STEM fields as an exciting field with real options.”
- “In the interest of quality STEM education, it is important to expose students to the team work required in a professional technical setting, where people of various backgrounds bring with them diverse lexicons and points of view to projects- a situation that can at first present challenges, but if handled with perseverance, patience, and an open mind can lead to synergistic results.”
- “This opportunity has redefined my career goals. I now have a greater want to do something bigger in this world. I now wish to pursue my PhD in chemistry to ultimately be a researcher at NASA. There are so many more career paths that have opened up for me. This is the best way to encourage students to do these projects to their maximum capabilities.“
- “I learned so much just by being in contact with this program, about NASA ops, design for microgravity ops, engineering project management, technical presentation and documentation...the list goes on.“
- “The entire process my team had to go through in order to fly was an incredibly tough, but rewarding process. The intangibles that I have learned the past 9 months leading up to the flight are invaluable.”
- “The overall experience was very good. There was a lot of hard work to get here, but the pay off was phenomenal.”
- “The entire experience was excellent. It would appear from the data that our hypothesis was correct, which makes the journey worth every minute. The thoroughness by which all our documentation and mechanics were scrutinized by most definitely causes us to “up our game” and grow. I would recommend this program to others thinking about trying their hands at it.”
- “We got good data in the experiment. The program was well set up to make our experiment succeed.”
- “What an amazing experience! My team and I really enjoyed our time here at Ellington Field. Although it was a lot of hard work, it was very worth it. I am very grateful for the opportunity and I hope this program continuous to inspire future students.”
- “I feel that the program is run wonderfully, and every one at NASA involved with the program was very helpful and friendly. I will never forget this experience and it has greatly helped me in further deciding my future and what I want to spend my life doing. Thank you!”
- “Overall a great program. Everyone in the education department was amazing and willing to go the extra mile to ensure our comfort and the success of our experiment. Thanks for a truly inspiring week.”
- “This was an amazing program. This has truly been a life-changing experience. I have learned so much in only several months, from designing and machining to proper flight practice and logistical preparations. I can definitely say this program has made me a better student, future engineer, and person.”
- “All of the staff involved did a superb job with coordinating my time at the program. This is definitely something that should be continued in the future.“
- “Personally, this has recharged my batteries for education, and I have never felt such an intense motivation to get back to my college and my lab and continue to work with our research. I am also going to look into other opportunities NASA offers. It looks like I have found the outlet I have been looking for.”
- “I cannot thank NASA, Microgravity University, and all of the program and flight staff for this opportunity. We will be taking a lot of good data back to our university, as well as enthusiasm and materials for outreach in our region.”

“There is nothing quite like it and even after working for NASA this is like the Holy Grail for every kid who dreams of being an astronaut - you get to experience microgravity.”

Appendix 4 – Summary Participation

PARTICIPATING STATES: 1997 – 2011

Forty-nine (49) states have participated in the Reduced Gravity Education Flight Program plus DC and Puerto Rico. The one state that has yet to participate is Delaware.



	States Flown	49*
	States Never Flown	1

*plus DC & Puerto Rico

Appendix 5 – 1997-2011 Participating University Status

3,389 Student Flyers (does not include ground crew)
212 Institutions / 696 Teams / 49 States (plus DC & Puerto Rico)

Institution Participation:					
AK	Univ of Alaska Fairbanks	CO	US Air Force Academy	KS	University of Kansas
AL	Alabama A&M	CO	Univ of Colorado-Boulder	KS	Wichita State University
AL	Auburn Univ.	CT	Fairfield University	KY	Eastern Kentucky University
AL	Tuskegee Univ	CT	Wesleyan Univ	KY	Univ of Kentucky
AL	University of Alabama-Birmingham	CT	Yale University	LA	Louisiana State Univ
AL	University of Alabama-Huntsville	DC	George Washington Univ	LA	Louisiana Tech Univ
AL	University of Alabama-Tuscaloosa	FL	Broward Community College	MA	Harvard University
AR	Univ of Arkansas	FL	Embry-Riddle Aeronautical University	MA	Massachusetts Inst of Tech
AR	University of the Ozarks	FL	Florida A&M University	MA	Smith College
AZ	Arizona State Univ	FL	Florida Institute of Technology	MA	Tufts Univ
AZ	Embry-Riddle Aeronautical Univ-Prescott	FL	Florida State Univ	MA	U Massachusetts-Lowell
AZ	No Arizona Univ	FL	Palm Beach State College	MA	Wellesley College
AZ	University of Arizona	FL	Saint Leo College	MD	Johns Hopkins University
CA	Cal State-San Marcos	FL	State College of Florida, Manatee-Sarasota	MD	United States Naval Academy
CA	California Institute of Technology	FL	University of Florida	MD	Univ of Maryland-College Pk
CA	California Polytechnic University	FL	Univ of Miami	ME	Univ of Southern Maine
CA	California State Polytechnic Univ, Pomona	GA	Georgia Institute of Tech	MI	Hope College
CA	California State University, Fresno	GA	Morehouse School of Med.	MI	Michigan Technological Univ
CA	Citrus College	GA	State Univ of West Georgia	MI	Univ of Michigan – Ann Arbor
CA	Foothill College	GA	Univ of Georgia	MI	Univ of Michigan-Dearborn
CA	Fullerton College	HI	Windward CC	MN	Univ of Minnesota-Minneapolis
CA	Grossmont College	IA	Iowa State	MO	Drury College
CA	Harvey Mudd College	IA	University of Iowa	MO	Missouri Univ Sci & Tech
CA	Lake Tahoe Community College	IA	University of Northern Iowa	MO	University of Missouri
CA	Los Medanos College	ID	Boise State Univ	MO	Washington Univ-St. Louis
CA	Pomona College	ID	Shonshone-Bannock	MS	Mississippi State Univ
CA	San Diego City College	ID	Northwest Nazarene Univ	MS	Univ of Southern Mississippi
CA	San Diego State Univ	ID	University of Idaho	MT	Dull Knife Mem Tribal College
CA	San Francisco Art Institute	IL	Northwestern Univ	MT	Montana State Univ-Billings
CA	UC-Berkeley	IL	Univ of Illinois-Chicago	MT	Montana State Univ-Bozeman
CA	UC-San Diego	IL	Univ of Illinois-Urbana/ Champaign	NC	Duke University
CA	Univ of San Diego	IN	Ivy Tech CC of Indiana	NC	North Carolina A&T State Univ
CA	Univ of Southern California	IN	Purdue University	NC	North Carolina State
CO	Colorado School of Mines	IN	Rose-Hulman Inst	NC	UNorth Carolina-Charlotte
CO	Colorado State Univ	IN	Taylor University	NC	UNorth Carolina- Pembroke
CO	Comm College of Aurora	KS	Pittsburg State	ND	North Dakota State Univ

ND	Univ of North Dakota	OR	Western Oregon University	TX	Texas State University
NE	Univ of Nebraska – Lincoln	PA	Carnegie Mellon	TX	Texas Southern University
NH	Dartmouth College	PA	Drexel Univ	TX	Texas Tech
NJ	College of New Jersey	PA	Lehigh University	TX	Univ of Houston
NJ	Princeton Univ	PA	Penn State Univ	TX	Univ of Houston-Clear Lake
NJ	Rowan University	PA	University of Pittsburgh	TX	UT-Austin
NM	New Mexico State	PA	University of Pennsylvania	TX	UT-Dallas
NM	New Mexico Tech	PR	Univ of Puerto Rico-Rio Piedras	TX	UT-El Paso
NM	Univ of New Mexico	PR	Univ of Puerto Rico-Mayaguez	TX	UT-San Antonio
NV	Univ of Nevada-Reno	RI	Brown Univ	UT	Brigham Young
NY	Alfred University	RI	Community College of Rhode Island	UT	Univ of Utah
NY	Cornell University	RI	Univ of Rhode Island	UT	Utah State Univ
NY	Fordham University	SC	Clemson University	VA	Virginia Tech
NY	Polytechnic University	SC	College of Charleston	VT	Norwich Univ
NY	Rochester Inst of Technology	SD	South Dakota School of Mines & Technology	VT	Univ of Vermont
NY	State Univ of New York Buffalo	TN	Rhodes College	WA	Seattle Central Community College
NY	Syracuse Univ	TN	Tennessee State University	WA	Seattle Pacific Univ
NY	United States Military Academy	TN	Tennessee Technological University	WA	Seattle Univ
OH	Case Western Reserve Univ	TN	University of Tennessee	WA	Tacoma Community College
OH	Ohio Northern Univ	TX	Austin Community College	WA	Univ of Washington
OH	The Ohio State Univ	TX	Collin County Community College	WA	Washington State
OH	Univ of Cincinnati	TX	El Paso Community College	WI	Carthage College
OH	Univ of Toledo	TX	Lamar Univ	WI	Ripon College
OK	Oklahoma State University	TX	Prairie View A & M Univ	WI	Univ of Wisconsin-Madison
OK	Univ of Oklahoma	TX	Rice Univ	WV	Bethany College
OK	Univ of Tulsa	TX	San Jacinto College-North	WV	Marshall Univ
OR	Oregon Inst of Technology	TX	S.F. Austin St Univ	WV	West Virginia University
OR	Oregon State Univ	TX	Texas A&M Univ	WY	Univ of Wyoming
OR	Portland State University	TX	Texas Christian Univ		

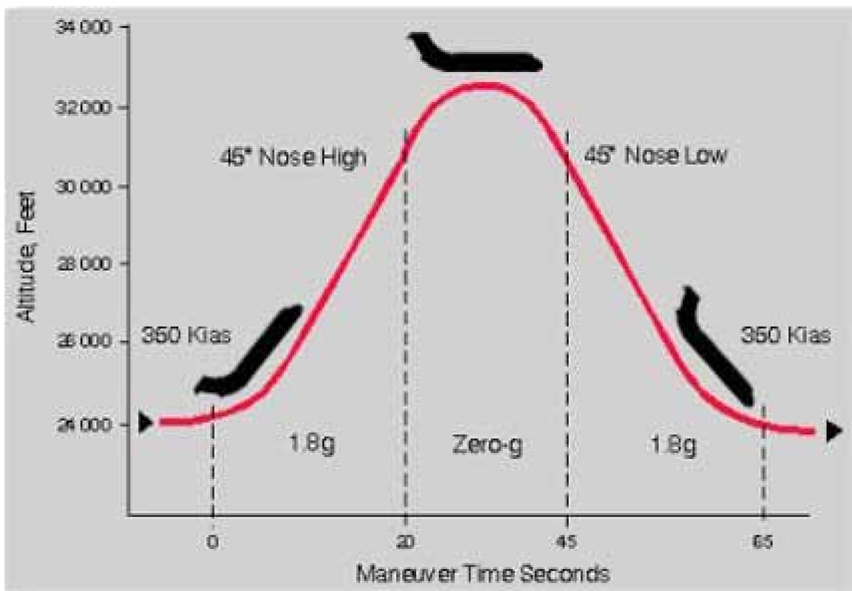
2011 participants are highlighted in blue

Group photo from the Minority-Serving Institutions and Community College flight week.

Appendix 6 – About the Microgravity Aircraft

The NASA-JSC Reduced Gravity Research Program flies on a modified Boeing 727 aircraft. The aircraft is crewed by a pilot, a copilot, a flight engineer, and two reduced gravity test directors. For the student campaign, a flight doctor, two video crew members and two photographers are also on board. Most test equipment is bolted to the floor using 20-inch tiedown grid attachment points.

The reduced gravity aircraft generally flies 30 parabolic maneuvers over the Gulf of Mexico. This parabolic pattern provides about 30 seconds of hypergravity (about 1.8G-2G) as the plane climbs to the top of the parabola. Once the plane starts to "nose over" the top of the parabola to descend toward Earth, the plane experiences about 18-25 seconds of microgravity (0G). At the very top and bottom of the parabola, flyers experience a mix of partial G's between 0 and 1.8 (called "dirty air").



Appendix 7 – Program History

Reduced Gravity Program Beginnings: In 1995, Ellington Field's Aircraft Operations Chief, Bob Naughton, accompanied NASA's reduced gravity aircraft to Europe to fly the European Space Agency's student parabolic flight campaign. Mr. Naughton, impressed with the success of ESA's flights, discussed the idea of a US parabolic flight campaign with NASA Headquarters and Johnson Space Center managers. Headquarters Education Chief Frank Owens liked the idea, as did (then) Deputy JSC Director George Abbey. In the summer of 1995, Abbey and Owens (with the support of the Texas Space Grant) prototyped the first US student parabolic flights.

1995 A pilot program was designed to provide a reduced gravity research opportunity for four teams of college seniors and graduate students from Texas' Rice and Texas A&M universities. The pilot program was called SURF (Students Understanding Reduced Gravity Flight).

1996 The program was repeated during the summer of 1996, again with four teams from Texas institutions: Lamar University, Rice University, Texas A&M University and the University of Houston. In the fall of 1996, SURF was renamed "Reduced Gravity Student Flight Opportunities Program (RGSFOP)" and expanded to include universities nationwide.

1997 Spring 1997 flights provided research opportunities for twenty-three teams from fifteen states. For the first time, journalists were permitted to fly as "team members."

1998 The RGSFOP doubled program "slots" in 1998 to include forty-seven participating teams from thirty-seven institutions in twenty-four states.

1999 A second yearly competition was born in 1999, which allowed for flights in both spring and summer. Forty-four teams from thirty-three institutions in twenty-one states participated during summer 1999.

2000 RGSFOP hosted 48 teams in March 2000. Because of KC-135 maintenance delays, 34 teams selected to participate in the Summer 2000 program were shifted into Spring 2001 program slots.

2001 Forty-eight teams participated in the Spring 2001 RGSFOP. Thirty-three teams were those shifted from the Summer 2000 program; the remaining fifteen teams were selected during the Spring 2001 competition.

2002 The Aerospace Academy (a division of San Jacinto College) accepted administrative responsibilities for the Reduced Gravity Student Flight Opportunity Program. The Microgravity University Office was born. A program coordinator and deputy coordinator, under the direction of Dr. Donn Sickorez, assisted the fifty-one teams who participated in the Spring and Summer flight weeks for the 2002 campaign.

2003 A record number of seventy-two teams were chosen to participate. Among these were seventeen first-time institutions and eleven minority teams. In addition, the program experienced an increase in minority participation.

2004 The RGSFOP extended offers to participate to sixty-nine student teams. Three NASA Explorer Schools and one Informal Education team were also invited to participate as part of a pilot program. Although the student program has been in existence in some form for nearly a decade, it is continuing to reach new audiences. This year, six new institutions and seven minority institutions were among the selected teams. This was also the last student group to experience reduced gravity on the KC-135.

2005 The program moved to the C-9 aircraft. Modifications and issues with the aircraft caused delays and cancellations. In all, only ten teams and thirty-two students flew. Teams were rolled over to the 2006 program.

2006 Flights returned to normal, as sixty-five teams are selected from 2005 and 2006 proposals. The first teams from Kansas, Pittsburg State and University of Kansas, fly their experiments. In addition, the first full group of museums and science centers are flown.

2007 In addition to the typical zero gravity parabolas, the student program's first lunar gravity experiments are flown. Lamar University, Michigan Technological University, and University of Missouri-Rolla flew experiments for 30 parabolas at 1/6G. Experiments ranged from lunar dust removal to welding.

2008 The program changed its name to the Reduced Gravity Education Flight Program (RGEFP) to reflect the teacher components. Two additional programs were added: Network of Educator Astronaut Teachers (NEAT) and the Systems Engineering Educational Discovery Program (SEED). Three states were also added to the participating states (Nebraska, Alaska, and Maine).

2009 The program moved to a contractor Boeing 727 aircraft. Through the special opportunities flight week, internal partnerships were explored as well as revisiting the policies of human-testing and the high school program.

2010 Four additional partnerships were added: The NASA Explorer Schools (NES) Opportunity flight week brought additional teams representing NASA Science, Engineering, Mathematics and Aerospace Academy (SEMAA) and Motivating Undergraduates in Science and Technology (MUST). An additional flight week was developed in conjunction with NASA Teaching from Space (TFS) Office and National Science Teachers Association (NSTA). Also added were two flight teams from the U.S. Department of Energy (DOE) in conjunction with the Princeton Plasma Physics Laboratory (PPPL).

2011 The total number of participants exceeded 500 individuals during the flight season, which is a record for the program. Also, three additional partnerships were added: The NASA Headquarters Office of Education provided funding for a flight week that focused on minority-serving institutions and community colleges. The National Space Grant Consortium funded a flight week for first-time participants. An official collaboration between the Reduced Gravity Education Flight Program and Princeton Plasma Physics Laboratory was established.

Program Support

To successfully complete the flight season, it takes the effort and generous support of numerous groups and the Reduced Gravity Education Flight Program would like to take this opportunity to thank the following organizations and individuals.

NASA Funding Sources

Exploration Science Mission Directorate
High Schools United with NASA to Create Hardware (HUNCH)
JSC Teaching from Space Office
National Space Grant Consortium
NASA Office of Education
Space Operations Mission Directorate
U.S. Department of Energy: Princeton Plasma Physics Laboratory

Other Sources

State Space Grant Consortium for supporting their flight teams

Proposal Evaluation Support

Undergraduate Technical Review Manager – John McQuillen (Glenn Research Center)
Undergraduate Technical Review Manager – Edward Jeffries (Marshall Space Flight Center)
Technical Reviewers from Glenn Research Center, Johnson Space Center and Marshall Space Flight Center
Safety Reviewers from Johnson Space Center – Dominic Del Rosso, Christopher Nelson and Fernando Zumbado
Education Outreach Reviewers from Johnson Space Center

Program Support

Ellington Field		**Mentors**		
Lead Test Director	Dominic Del Rosso	David Alexander	Darrell Jan	Sarah Ruiz
Test Director	Terry Lee	Camille Alleyne	Christopher Johnson	Amy Schellhase
Office Manager	Rose Aquilina	John Alred	Michelle Jones	Rubik Sheth
Office Support	Kerry McManis	Ronald Baccus	Alex Kanelakos	Jason Smith
Engineer	Alan Flint	Laura Beachy	Carolynn Kanelakos	Kelly Soich
Engineer	Bobby Roe	Ernest Bell	James Krzmarzick	Wesley Tarkington
	Noel Caasi	Elizabeth Blome	David Lantz	Ashley Tarpley
	Cap Nguyen	Cody Burkhart	Kerry Lee	Corey Theriot
	Aircraft Operations	Miguel Castillo	Thomas Leimkuehler	Jessica Tramaglini
	Engineering Department	Tess Caswell	Eduardo Llama	Robert Trevino
	Safety Office	Rebecca Cutri-Kohart	Ben Longmier	Sally Vail
Flight Medicine Clinic		Manohar Deshpande	Larry McCormick	Christy Varshese
Lead	Dr. James Locke	Jonathan Dory	Nujoud Merancy	Mana Vautier
	Flight Surgeons	Michael Flynn	Philip Metzger	Howard Wagner
	Staff Members	Christina Gallegos	David Miller	Scott Walker
Imagery Acquisition Group		Amber Gell	Ashley Milne	Aaron Weaver
Human Test Support Group		Tamra George	Christopher Nelson	Rudy Werlink
Supervisor	Mike Fox	Johanna Goforth	Gregory Pace	Susan Winnitoy
	Javier Roque	Jeremy Hart	Mark Pape	Honglu Wu
	Susan Crosbie	Robert Hirsh	Zarana Patel	Jennifer Zumbado
	Staff Members	Todd Isaacson	Carolina Restrepo	Carlie Zumwalt